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DAMPING-OFF OF TOMATO SEEDLINGS

By Babu Singh and H. C. Srivastava

Plant Pathological Laboratory, Govt. Agricultural College, Kanpur, U.P.

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The tomato crop suffers heavily all over the Uttar Pradesh in the seedling stage by 'damping-off'. The disease has been found to be of cosmopolitan occurrence and was investigated in foreign countries by Alexander, Young and Kiger (1931–32), and Brown (1944), but so far no comprehensive work has been done in India, on this problem. The disease has been noticed in various nurseries at Kanpur and its neighbouring villages for several years, both in the rainy and winter seasons, but the damage is especially severe during rains. The nursery owners usually raise seedlings in the same seedbeds, year after year, and thus suffer tragic losses due to this disease. The percentage of damage was estimated by throwing one foot hollow square in seedbeds at random, and then counting the affected and healthy seedlings inside the square. During the rainy season of 1947–48, the disease was surveyed in various nurseries of the State, and the average percentage of damage, is given below. Almost every seedbed in the locality mentioned below was found affected.

Kanpur ..	60–80%	Allahabad ..	60–70%
Unao ..	58–78%	Banares ..	62–64%
Kannauj ..	60–80%	Meerut ..	48–52%
Bulandshahr ..	50–60%	Agra ..	65–74%

Considering the economic importance of the crop and the losses caused by the disease, the present investigation was undertaken.

Symptoms

The disease is characterised by sudden collapsing of the seedlings in the seedbeds. The seedling begins to rot from the base resulting in its toppling over abruptly and then drying slowly from base to the top. In a few cases the disease started from the root hairs and killed the seedlings in the same way (Fig. 1 A). Some of the seedlings, even at an early age, become twisted at their base and brown spots appear on their roots. Top infection is also common, whereby the upper portion of the seedling rots first, while the lower portion remains normal (Fig. 1 B). Such seedlings are often associated with the disease at their base as well, which ultimately hastens their mortality. Brown

and dark brown lesions are formed on some of the seedlings, encircling any part of their stout stem, hence forming a 'Sore-Shin'. Constricted lesions, shining milky white in colour, are formed at the base of the stem and young white sclerotia, which at later stage turn brown are attached to it. Local lesions, brown to dark tan in colour, with margins showing violet tinge, are found on the affected portion of the seedlings. Black pycnidia are seen on the surface of the lesions. When a seedling after infection topples over suddenly and touches the ground by its middle portion, secondary roots are given out at the point of contact with the soil, the upper part of the seedling remains normal.

"Pre-emergence" damping-off, *i.e.*, rotting of the seeds and the seedlings before actual emergence from the soil is also very common, and as a result of this, scattered small blank patches are usually found in the seedbeds. "Post-emergence" damping-off is severe when the seedlings are in cotyledonous stage, and this is the "critical period" for them. The disease is also common even after the formation of the secondary leaves.

Isolation of Causal Organisms

The diseased seedlings of tomato were collected from various places, and large-scale isolations from them revealed the presence of the following fungi. The percentage occurrence of each fungus in the isolations is given below:—

1.	*Pythium sp.* No. 1.. ..	90%
2.	*Pythium sp.* No. 2.. ..	55%
3.	*Phytophthora sp.*	60%
4.	*Rhizoctonia sp.*	82%
5.	*Sclerotium rolfsii*	25%
6.	*Phoma sp.*	20%
7.	*Fusarium sp.*	15%
8.	*Acrothecium sp.*	5%
9.	*Alternaria sp.*	4%
10.	*Helminthosporium sp.* ..	2%

Pythium sp. No. 1 was invariably found associated with *Phytophthora sp.*, but it was obtained in the pure form by inoculating the mixture of the two fungi on Bhindi buds (*Hibiscus esculentus* L.). On the other hand *Phytophthora sp.* was recovered in the culture free from *Pythium sp.*, by inoculation on Castor leaves (*Ricinus communis* L.) and re-isolating it from inoculated leaves. The parasitic fungi (Table II) were studied in detail.

Morphology and Identity of the Fungi

Pythium sp. No. 1.—Hyphæ 4–12 μ in diameter; appressoria 10–30 μ, sporangia (prosporangia) had a linear structure, 80–250 μ in length and an evacuation tube was given out from it, which was broader than hypha and longer than sporangium. A vesicle was formed at the tip of evacuation tube in which zoospores were formed, they measured 12–15 μ while swimming and 10 μ when encysted. They germinate

by producing 1–3 germ tubes. Terminal oogonium measured 15–20 μ and had a tendency to bend towards antheridium. The antheridia were monoclinous, oospores aplerotic, thickwalled and measured 10–20 μ, with an average of 15·5 μ, oospores were formed in clusters at one place (Fig. 2). The species agreed with the measurements and

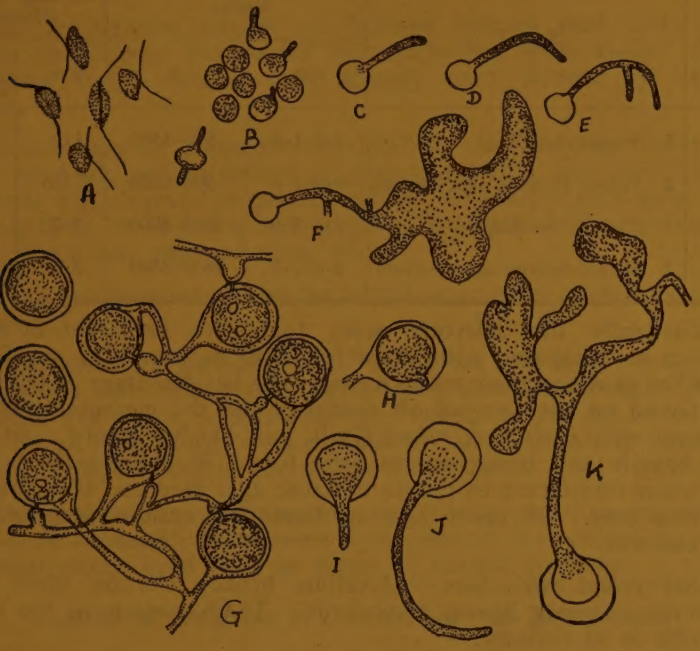

FIG. 2. *A*. Biciliated zoospores as they swim, ×1,100. *B*. Encysted zoospores germinating *in situ*, ×1,100. *C, D, E & F*. Various stages of germination of zoospores, ×1,100. *G*. Oospores formed in cluster from a strand of hypha, ×600. *H, I, J & K*. Various stages of germination of oospores, ×600.

characters of *Pythium indicum* Balakrishnan, reported by Balakrishnan (1948) from Madras (South India) causing the fruit rot of Bhindi (*Hibiscus esculentus* L.).

Pythium sp. No. 2.—The hyphæ unseptate, measuring 3–7 μ but septa were present in older ones. The zoospores were 8–12 × 6–8 μ while moving and 8–9 μ at rest. Oogonia were 20–26 μ in diameter and formed generally on short lateral stalks. Oospores round, smooth and measured 14–22 μ in diameter. The species was identified as *Pythium aphanidermatum* (Edson) Fitz.

Phytophthora sp.—Hyphæ 5–6 μ in width, sporangia borne on simple stalk, varying in size from 25–50 × 20–40 μ. Zoospores 8–12 μ while moving and 7–11 μ during rest. Chlamydospores 20–60 μ in diameter, oogonium 15–27 μ with an average of 23·8 μ in diameter. Oospores ranged from 13–27 μ but generally 15–20 μ in diameter. The species was identified as *Phytophthora parasitica* Dastur.

Rhizoctonia sp.—Mycelium 7–9 μ in diameter and the cells were 40–130 μ long. Two different sizes of sclerotia were found in nature as well as in culture medium named as type A and B. Their measurements are tabulated below:—

Type	Source	Range		Average of 200 sclerotia	
		mm.	μ	mm.	μ
A	1 Tomato seedlings ..	0·9–1·5	900–1500	1·2	1200
	2 Potato dextrose agar medium	0·9–1·8	900–1800	1·35	1350
B	1 Tomato seedlings ..	2·5–3·0	2500–3000	2·7	2700
	2 Potato dextrose agar medium	2·8–3·5	2800–3500	3·1	3100

Generally the sclerotia were found to be larger in culture medium as compared with those found in nature. The species was identified as *Rhizoctonia solani* Kuhn. The basidial stage of the fungus was found on the damped-off seedlings and the measurements were identical with *Corticium solani* (Prill. and Declr.) Bourd. and Galz. The basidia and basidiospores were found in abundance in nature but when transferred to potato dextrose agar medium, they produced sclerotia only. On onion agar medium, few basidia were found, in old cultures.

Sclerotium rolfsii Sacc.—Mycelium broad, sclerotia white in the beginning, turning brown afterwards. The variation in the size of sclerotia is as follows:—

Serial No.	Source	Range		Average	
		mm.	μ	mm.	μ
1	Tomato tissues ..	0·4–1·5	400–1500	0·95	950
2	Potato dextrose agar medium ..	1·0–2·0	1000–2000	1·5	1500
3	Maize meal agar ..	0·9–2·5	900–2500	1·7	1700

Phoma sp.—Mycelium first hyaline but later on turned light brown in colour, and was generally inter-cellular. Pycnidia light brown to dark in colour, and found below the epidermis. There was much variation in their size, *e.g.*, from 130 μ to 420 μ but the largest number fell between 180–350 μ. The pycnospores also vary in size, and the largest number fell between 3·5–7·0 μ in length and 2·5–3·9 μ in breadth out of 200 measurements. The species was identified as *Phoma betæ* (Oudem) Frank.

Fusarium sp.—Mycelium aseptate, conidia formed on short conidiophores were hyaline, falcate and acute. Both micro and macro-conidia were abundant in cultures. Macro-conidia were 3–5 septate.

Germination Studies of *Pythium indicum* Balakrishnan

The germination studies of *Pythium indicum* were undertaken because no account has so far been published from India. Other pathogenic fungi isolated have already been studied by various authors.

Germination of zoospores in distilled, sterilised, tap water and in 0·1 to 4·0% concentrations of glucose solution was done but no difference was observed in the treatments. Oogonium gave germ tube in water from 24–48 hours and oospores from 4–8 days when kept in water, which was changed twice daily.

Sporangia were formed by the mycelium given by zoospores within 24 hours.

In darkness the germination of zoospores was only 1–3·5%, and no sporangia were formed from the mycelium given out by them. When sporangia were kept in darkness, they failed to give the evacuation tubes, but as soon as they were exposed to light, evacuation tubes were formed. Oospores did not germinate in darkness.

The germination of zoospores and formation of sporangia was very much enhanced, when some food material was placed in water, *e.g.*, agar pieces, dead ants or pieces of tomato seedlings.

Viability of Oospores of *Pythium indicum* Balakrishnan

Two methods were adopted to test the viability of the oospores:—

(i) The oospores were mixed with dry sterilised soil in a conical flask and kept at room temperature, in the laboratory. The range of temperature was 18–26° C. Suspension of oospores along with sterilised soil was prepared in sterilised water. Drops from it were kept on sterilised slides and the percentage of germinated oospores was noted. This was repeated every fortnightly, to determine the viability of oospores of different ages. (ii) Drops of the suspension of oospores in sterilised water were kept on sterilised slides and were allowed to dry inside a sterilised Petri dish. Such dried oospores were again moistened with sterilised water, after definite intervals and the percentage of germination was noted and the results are tabulated in Table I.

It is evident from Table I, that the percentage of germination of oospores is adversely affected by age and exposure to dry conditions. The oospores kept in soil remained viable for more than 150 days whereas when they were dried on slides, they germinated only upto 105 days. There was less germination with the increase in age of oospores.

TABLE I

Showing the viability of oospores of Pythium indicum

Age of culture days	% germination of oospores after													
	4 days		5 days		6 days		7 days		8 days		9 days		10 days	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
15	78·0	65·3	85·0	68·4	89·2	69·0	92·0	72·0	95·6	78·0	97·2	82·0	100·0	89·0
30	62·0	62·0	70·5	62·0	85·0	65·3	88·0	68·3	92·0	70·2	97·6	75·0	100·0	79·3
45	60·2	57·3	60·7	59·4	71·8	62·0	82·0	64·3	89·7	69·3	94·3	72·0	98·8	75·6
60	55·8	52·4	59·2	54·2	63·8	57·2	69·0	60·1	75·0	63·0	82·3	65·0	92·0	70·3
75	52·8	47·0	56·2	48·0	60·2	52·0	65·0	53·0	69·3	55·0	72·0	57·0	85·0	65·0
90	46·7	30·4	49·2	36·2	55·2	40·3	59·2	43·0	63·0	45·0	69·5	48·0	77·2	56·0
105	42·8	15·4	47·2	20·0	52·3	23·0	56·4	24·0	62·0	25·0	67·0	26·7	73·2	27·0
120	39·1	..	43·3	..	45·7	..	50·3	..	52·4	..	59·2	..	65·0	..
135	32·3	..	39·2	..	42·0	..	44·5	..	51·2	..	48·0	..	50·0	..
150	25·2	..	28·2	..	30·2	..	38·4	..	40·2	..	43·2	..	45·2	..

A = Germination percentage of oospores of *Pythium indicum* from sterilised soil.
B = ,, ,, ,, ,, ,, ,, dried on slides.
.. denotes nil.

Pathogenicity

A number of inoculation experiments to test the pathogenicity of different fungi isolated were carried out in the laboratory. In one set of pots, sterilised soil was filled and thoroughly mixed with the fungus culture grown on corn meal sand, and the seeds were sown. In the second set of pots, seeds were sown in sterilised soil and then the soil was watered with spore suspension. In the third set of pots,

TABLE II

Summary of the inoculation experiments carried out with different fungi isolated from Tomato seedlings

Name of the fungus	I Set		II Set		III Set		IV Set	
	%E	%D	%E	%D	%E	%D	%E	%D
P. indicum ..	69·0	83·4	73·0	63·1	55·0	90·2	92·0	..
P. aphanidermatum ..	58·0	80·5	79·0	58·0	65·0	82·2	92·5	..
R. solani ..	74·0	82·4	79·0	60·1	60·0	80·6	93·0	..
Phytophthora parasitica ..	78·0	55·6	88·0	43·9	71·0	58·1	92·0	..
Sclerotium rolfsii ..	14·0	85·1	75·0	30·2	17·0	82·0	94·0	..
Phoma betæ ..	88·0	32·8	92·0	10·0	84·0	36·7	92·0	..
Fusarium sp. ..	85·0	19·4	88·0	8·7	83·0	29·2	93·0	..

E = emergence. D = damage. .. denotes nil.

the seeds were sown in sterilised soil mixed with fungus culture and then the latter was watered with spore suspension. In the fouth set, the seeds were sown in sterilised soil in pots to serve as control. The emergence and damage percentage as observed in each case is given in Table II.

The above table shows that *Pythium indicum* Balakrishnan, *Pythium aphanidermatum* (Edson) Fitz., *Rhizoctonia solani* Kuhn., *Phytophthora parasitica* Dastur, *Phoma betæ* (Oudem) Fr., *Sclerotium rolfsii* Sacc., and *Fusarium sp.* are pathogenic while *Alternaria sp.*, *Helminthosporium sp.*, and *Acrothecium sp.* are non-pathogenic. *Pythium indicum* proved to be the most destructive organism.

Inoculation of seedlings of different ages.—Experiments were set in which 3 days to 5 weeks-old seedlings were inoculated with different fungi in order to see their virulence in relation to the age of the host. The fungus was inoculated by several methods, *i.e.*, by keeping the fungus culture by the side of hypocotyl of the seedlings, by spraying spore suspension on the seedlings, and by spraying spore or sclerotial

suspension on the soil. Twelve seedlings were inoculated in each set, and the number of damped-off seedlings were counted and tabulated in Table III. The seedlings were sprayed with distilled water for control.

TABLE III

Showing the number of damped-off seedlings of different ages on inoculation by different methods

Name of fungus	Method of inoculation	Age of the seedlings					
		3 Days	1 Week	2 Weeks	3 Weeks	4 Weeks	5 Weeks
Pythium indicum	*a*. Culture on hypocotyl ..	12	10	9	6	5	1
	b. Zoospore suspension on seedlings	10	10	8	7	7	4
	c. Zoospore, oospore suspension in soil	12	8	6	5	..	..
Pythium aphanidermatum	*a*. Culture on hypocotyl ..	12	10	10	5	6	4
	b. Zoospore suspension on seedlings	10	8	7	5	3	..
	c. Zoospore, oospore suspension in soil	11	7	4	3	..	..
Phytophthora parasitica	*a*. Culture on hypocotyl ..	10	11	9	6	5	..
	b. Zoospore suspension on seedlings	8	7	6	5	..	..
	c. Zoospore, oospore suspension in soil	10	8	7	4	2	..
Rhizoctonia solani	*a*. Culture on hypocotyl ..	10	11	10	9	8	8
	b. Sclerotial suspension in soil ..	8	7	9	8	6	4
Phoma betæ	*a*. Culture on hypocotyl ..	8	7	8	6	7	7
	b. Spore suspension in soil ..	6	7	7	6	6	6
Fusarium sp.	*a*. Culture on hypocotyl ..	4	3	2	4	2	..
	b. Spore suspension in soil ..	3	2	1	..	..	..
Sclerotium rolfsii	*a*. Culture on hypocotyl ..	2	1	2	3	1	2
	b. Sclerotial suspension in soil ..	5	2	..	..	..	..
Sterilised soil (control)	Distilled water sprayed ..	..	..	..	..	..	..

.. denotes nil.

It is evident from Table III that *Pythium* species infect seedlings of all ages tested in the nurseries, but the older seedlings were less susceptible to *Phytophthora parasitica* Dastur. *Phoma betæ* (Oudem) Fr. and *Rhizoctonia solani* were found to infect old seedlings. There was no disease in contol.

Inoculation experiments with different fungi in combination.—In order to see the effect on incidence of the disease, when more than one pathogenic fungus were present in the soil, an experiment was laid out

in which different combinations of the fungi were mixed with sterilised soil and 100 seeds were sown in each pot (size: Diameter 2 ft., height 6 inches). The percentage damage is tabulated in Table IV. Seven flasks of the fungus culture, grown on corn meal sand, were thoroughly mixed in each pot used in the experiment and where more than one fungus was used, equal proportions of the inoculum from different fungi were kept. The data from inoculation of individual fungus is given in Table II, in I set of pots and the damping-off percentage is the total of pre- and post-emergence loss; and has not been repeated in Table IV.

TABLE IV

Summary of the inoculation experiments carried out with combinations of pathogenic fungi

Different combinations of fungi	% Emergence	Damping-off %		
		Pre-	Post-	Total
Sterilised soil + seeds ..	88	..	..	..
P. indicum + *P. aphanidermatum* ..	38	50	38	88
,, + *R. solani* ..	36	52	39	91
,, + *Phoma betæ* ..	60	28	46	74
,, + *Fusarium sp.* ..	74	20	47	67
,, + *Phytophthora parasitica* ..	59	29	47	76
,, + *Sclerotium rolfsii* ..	50	38	6	44
R. solani + *Phytophthora parasitica* ..	62	30	44	74
,, + *Phoma betæ* ..	62	16	21	37
,, + *Fusarium sp.* ..	60	20	18	38
,, + *S. rolfsii* ..	60	28	5	33
,, + *P. aphanidermatum* ..	34	54	32	86
Phytophthora sp. + *Phoma betæ* ..	76	12	26	38
,, + *Fusarium sp.* ..	78	10	22	32
,, + *S. rolfsii* ..	53	36	8	44
Phoma betæ + *Fusarium sp.* ..	82	6	8	14
,, + *S. rolfsii* ..	30	58	2	60
Fusarium sp. + *S. rolfsii* ..	32	56	2	58
Pythium spp. + *R. solani* + *S. rolfsii* ..	38	50	35	85
,, + ,, + *Phytophthora sp.* ..	36	54	42	96
,, + ,, + *Fusarium sp.* ..	51	37	20	57
,, + ,, + *Phoma betæ* ..	56	32	32	64
R. solani + *S. rolfsii* + *Phytophthora sp.* ..	58	30	40	70
,, + ,, + *Fusarium sp.* ..	65	23	12	35
,, + ,, + *Phoma betæ* ..	64	24	25	49
S. rolfsii + *Phytophthora sp.* + *Fusarium sp.* ..	62	26	10	36
,, + ,, + *Phoma betæ* ..	60	28	5	33
Phoma betæ + *Fusarium sp.* + *Phytophthora sp.* ..	75	13	8	21
Pythium spp. + *R. solani* + *S. rolfsii* + *Phytopth. sp.* ..	38	50	40	90
,, + ,, + ,, + *Fusarium sp.* ..	48	40	28	68
,, + ,, + ,, + *Phoma betæ* ..	50	38	25	63
Phytophthora sp. + ,, + ,, + ,, ..	49	39	25	64
,, + ,, + ,, + *Fusarium sp.*	46	42	22	64
,, + *Phoma betæ* + ,, + ,, ..	45	43	19	62
All pathogenic fungi mixed ..	36	52	47	99

The data show that *Pythium* singly (refer Table II, Set I) as well as in combination is the most virulent parasite, while *S. rolfsii* loses its virulence in combination. The damage becomes maximum when *Rhizoctonia sp.*, *Pythium spp.*, and *Phytophthora sp.* were mixed and introduced into the soil.

Cross-Inoculation

The fungi isolated from damped-off tomato seedlings were introduced in the sterilised soil and the seeds of different vegetables and ornamentals were sown in it. Similarly the fungi isolated independently from different damped-off vegetable and ornamental seedlings were inoculated in the soil and tomato seeds were sown. The results of the experiment show that the fungi responsible for damping-off in tomato seedlings can also cause the disease in cabbage (*Brassica oleracea* var. *caulorapa*), cauliflower (*Brassica oleraceæ* var. *botrytis*), tobacco (*Nicotiana tobacum*) and balsamina (*Impatiens balsamina*) seedlings and *vice versa*.

Inoculation experiments on different varieties of tomato.—The virulence of these fungi was tested on different varieties of tomato. Three varieties were selected, in which Marglobe was an improved one, having fast growth and yielding big fruits. The second one was Pondorosa, a medium and the third one Oxheart, a slow growing, short statured and yielding small fruits. The percentage of pre- and post-emergence damping-off is tabulated in Table V.

TABLE V

Showing the inoculation of different fungi on different varieties of tomato

Name of the fungus	Marglobe % damage		Pondorosa % damage		Oxheart % damage	
	Pre-	Post-	Pre-	Post-	Pre-	Post-
P. indicum ..	25	60	15	50	9	30
P. aphanidermatum ..	24	55	12	40	4	20
Phytophthora parasitica ..	20	40	12	32	..	12
Rhizoctonia solani ..	15	58	10	42	2	14
Phoma betæ ..	8	28	4	20	..	4
Fusarium sp. ..	6	15	2	8	..	..
Sclerotium rolfsii ..	75	8	70	..	52	..

'Pre-' stands for pre-emergence loss.
'Post-' stands for post-emergence loss.

From the above table it is quite clear that Marglobe is easily susceptible, while Oxheart is less. Marglobe is a prominent variety but is heavily attacked by the disease.

Control Measures

The study of the problem reveals that the disease generally starts from the soil, therefore, all attempts were made to destroy the fungi in the soil or to protect the seeds through seed treatments from their invasion. A number of the fungicides were compared to see their efficacy in controlling the disease, in statistically laid out plots and their results were analysed and interpreted.

A. Seed treatments.—Nine fungicides were used for seed treatment, *viz.*, Agrosan G, Ceresan, Spergon, Phygon, Zinc oxide, Copper carbonate, Copper sulphate, Formalin and Mercuric chloride. To ascertain the best strength of Copper sulphate, Formalin and Mercuric chloride, to be used as seed treatment, an experiment was laid out in which the seeds were soaked in different percentage of the above fungicides and sown in the soil, which was already infested with the pathogenic fungi. The emergence and damping-off percentage was noted and the analysis of the results revealed that 3% Formalin (considering the commercial formalin as cent. per cent.); 3% Copper sulphate; 0·15% Mercuric chloride are the best strength which can be used safely. The rest of the fungicides were dusts, and the seeds were dusted with them. The excess of the dusts was shaken off.

In comparing the efficacy of all the above fungicides, the treated seeds were sown in soil inoculated with the causal organisms. For check (control), untreated seeds were sown in inoculated soil. To see the effects of various chemicals and fungicides on seed germination, treated seeds were also sown in sterilized soil. Pre- and Post-emergence damping-off were noted and the data was statistically analysed.

TABLE VI

Analysis of variance of Pre-emergence damping-off

Due to	Degrees of freedom	Sum of squares	Mean square
Blocks ..	3	7·2	2·4
Treatments ..	9	10259·3	1139·9
Fungi ..	4	1455·7	363·9
Treatments × Fungi ..	36	1124·5	31·2
Error ..	147	967·4	6·6
Total ..	199	13814·1	..

The above table denotes that the variation due to treatments is significant at 1% level and the symbolical representation of the average percentage of damped-off seedlings placed in order is as follows:—

Ceresan	Agrosan	Phygon	Zinc oxide	Spergon	Copper carbonate	Copper sulphate	Formalin	Mercuric chloride	Control
8·3	9·6	10·2	10·7	11·5	12·4	13·3	14·4	15·0	36·6

The above representation shows that Ceresan is the best fungicide for controlling Pre-emergence damping-off. Then comes Agrosan G, which is less efficacious in controlling the disease than Ceresan and is closely followed by Phygon. Though the percentage of damping-off in Phygon is slightly greater than that in Agrosan G, yet this difference is insignificant and can be attributed to random causes. Each and every fungicide is effective for reducing the disease percentage as obtained from Control.

TABLE VII

Analysis of variance of Post-emergence damping-off

Due to	Degrees of freedom	Sum of squares	Mean squares
Blocks ..	3	48·6	16·2
Treatments ..	9	19403·8	21559·9
Fungi ..	4	5206·5	1310·6
Treatments × Fungi ..	36	1800·7	500·2
Error ..			
Total ..	199	27416·8	..

The above table shows that the variation due to blocks, treatments, fungi, and interaction between different fungi and treatments are highly significant. The symbolical representation of the fungicides in controlling the post-emergence damping-off, in order of their fungistatic action is as follows:—

It is evident from the above representation that Copper sulphate and Formalin lessend the post-emergence damping-off, against Agrosan G and Ceresan, which proved better, in controlling pre-emergence

Copper sulphate	Formalin	Agrosan	Ceresan	Mercuric chloride	Copper carbonate	Zinc oxide	Control	Spergon	Phygon
22·6	27·5	35·9	41·1	45·0	45·6	49·1	51·1	51·7	51·9

damping-off. Copper carbonate and Mercuric chloride do not differ significantly among themselves. Spergon, Phygon and Control come under one line, it means that these two fungicides have no effect in controlling post-emergence damping-off. Since Ceresan and Agrosan G are better in controlling pre- and post-emergence losses as compared with other fungicides, therefore these are considered to be the best seed treatments.

B. Soil treatment (*before sowing*).—Formaldehyde dust was mixed with the soil before sowing the seeds. A number of experiments were laid out statistically to find out the proper absorbant and correct weight of the fungicide to be used. The formula is given below:—

Commercial formalin Absorbant 15 parts
(*a*) Wood charcoal .. .. 85 parts
(*b*) Charcoal ash .. .. .. 85 parts
(*c*) Soil (finely dusted) .. .. 85 parts

The dust was mixed to the upper 3 or 4 inches of the soil, and then the seedbed was covered with wax paper. The seeds were sown after several days of treatment. Six different weights were used, *viz.*, 8 gm., 16 gm., 24 gm., 32 gm., 40 gm. and 60 gm., per square foot. The data obtained was statistically analysed and interpreted as follows:

TABLE VIII

Analysis of variance

Due to	Degrees of freedom	Sum of squares	Mean squares
Weights ..	5	11151·0	2230·2
Fungi ..	4	590·7	147·7
Weight × Fungi ..	10	1591·1	79·6
Methods ..	2	75·4	37·7
Weights × Methods ..	10	107·4	10·7
Fungi × Methods ..	8	20·1	2·5
Fungi × Weight × Methods ..	40	75·0	1·9

The interaction between weights and methods, fungi and methods, fungi, weights and methods, were separately analysed and the symbolical representation for the different weights runs as follows:—

40 gm.	32 gm.	24 gm.	16 gm.	8 gm.	Check
10·7	12·5	14·1	18·7	22·3	43·6

Since 60 gm. per square foot delayed the seed germination and often caused injury to the seeds, therefore its data was not considered in the comparison. The representation shows that the use of 40 gm., 32 gm. and 24 gm., do not differ significantly, *i.e.*, the use of any of these weights will check the disease equally well, therefore to avoid the risks, 32 gm. per square foot, is considered to be the best treatment. The fungi have got definite effect in producing the disease and regarding, different methods of absorbants, the following is their symbolical representation:—

Charcoal ash	Charcoal powder	Soil
19·6	19·8	21·6

It denotes that the Charcoal ash is the best absorbant. Agrosan G and Ceresan had already been considered to be the best seed treatments and formaldehyde dust at the rate of 32 gm. per square foot, as best soil treatment. An experiment was therefore laid out in which the treated seeds with both the dusts were sown in beds, the soil of which was treated with formaldehyde dust. It was seen that the disease was absent from such beds (Figs. 1 C & E; D & F).

C. Controlling the disease after sowing.—Cheshunt compound and 2·5% formalin (commercial) were used as spray in the seedbeds to control the disease after sowing. An experiment was statistically laid out, in order to compare the above two fungicides. The seedbeds selected for the experiment were inoculated with the pathogenic fungi, as usual, leaving check beds to see the effect of the fungicide on the seedlings. The seeds were sown and the next day all the beds were sprayed with the above fungicides. The beds were then divided in three groups, in the first group, no subsequent spraying was done; in second, spraying was done every seventh day; while in the third, spraying was done every third day, and all this was maintained upto 21 days. The critical statistical study of the data revealed that spraying at every third day was better in the case of both the fungicides. Both of them stand on equal footing but cheshunt compound was slightly better, as formalin often kills the seedlings due to its toxic nature.

The results obtainzd from the experiments on controlling the damping-off in tomato, denote that, Ceresan is the best seed treatment and

Formaldehyde dust as the best soil treatment, at the rate of 32 gm. per square foot, applied to upper 3 or 4 inches layer of soil, a fortnight before sowing, while when they both were applied, the disease was found almost controlled.

Summary

Damping-off of tomato seedlings is a serious problem of nurseries. of Uttar Pradesh, and ten fungi were isolated from the diseased specimens, brought from several places. Out of them only seven could be proved pathogenic. These have been identified as *Pythium indicum* Balakrishnan, *Pythium aphanidermatum* (Edson) Fitz., *Phytophthora parasitica* Dastur, *Rhizoctonia solani* Kühn., *Sclerotium rolfsii* Sacc., *Phoma betæ* (Oudem.) Fr., and *Fusarium sp.*

A method of separating mixed cultures of *Pythium indicum* and *Phytophthora parasitica* was found out by inoculating them on *Hibiscus esculentus* and *Ricinus communis* respectively. The oospores of *Pythium indicum* were found to be viable for more than 150 days.

The pathogenic fungi infected the seedlings upto the age of 5 weeks. Varietal tests show that Marglobe is the most susceptible and Oxheart the least susceptible variety.

Various wet and dry seed treatments were carried out to control the disease, and statistical analysis of the data obtained shows that Ceresan is the best seed treatment in controlling pre-emergence damping-off.

Formaldehyde dust was used for soil treatment, and three different absorbants were taken, out of which Charcoal ash proved slightly better than others. Its application at the rate of 24–40 gm. per square foot of upper 3 inches of the soil proved to check the disease. A combined application of Ceresan as seed treatment, and formaldehyde dust at the rate of 24–40 gm. ($\frac{1}{2}$ — $\frac{3}{4}$ chattaks) per square foot, as soil treatment controlled the disease.

After sowing, spraying with 2·5% formaline and cheshunt compound checked the disease.

ACKNOWLEDGEMENT

The authors are greatly indebted to Dr. B. L. Sethi for encouragement and keen interest during the course of investigation and to the U.P. Scientific Research Committee for partly financing the work.

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LITERATURE CITED

1. ALEXANDER, L. J., YOUNG, H. C. AND KIGER, C. M. 1931. Causes and control of damping-off of tomato. Ohio. Agri. Expt. Bull. 496.
2. BALAKRISHNAN, M. S. 1948. South Indian Phycomycetes. I. *Pythium indicum* sp. nov. causing fruit rot of *Hibiscus esculentus* L. Proc. Ind. Acad. Sci., B, 27.

3. BEWEY, W. F. 1921. Control of damping-off and foot rot of tomatoes. Jour. Minn. Agr. (Gr. Brit.). 28: 653–54.

4. ————. 1920. Damping-off and foot rot of tomato seedlings. Ann. Appl. Biol. 7: 156–72.

5. BRIEN, R. M. AND CHAMBERLAIN, E. E. 1936. Tomato seedlings damping-off. I. Control by seed treatments. New Zealand Jour. Agr. 52: 257–67.

6. BROWN, W. 1941. Damping-off disease of tomato. Gardener's Chronicle Ser. 3, 109: 55.

7. BUTLER, E. J. 1907. Studies in the genus *Pythium*. Mem. Dept. Agr. India Bot. Series, Vol. I.

8. CUNNINGHAM, H. S. AND SHARVELLE, E. G. 1940. Organic seed treatments for lima beans. Abs. Phytopath. 30.

9. DASTUR, J. F. 1912. *Phytophthora parasitica*—a new disease of the castor oil plant. Mem. Dept. Agr. India Bot. Series. Vol. 5.

10. GODBOUT, F. L. 1930. Some studies of seed treatments. Canada Phyto. Sec. Prec. 47-54.

11. GUTTERMAN, C. F. AND MASSEY, L. M. 1935. A liquid formaldehyde treatment to control damping-off of flower seedlings. Abs. Phytopath. 25.

12. HAENSLER, C. M. 1935. Formaldehyde does well in controlling damping-off N.J. Agr. 17: 1.

13. HIGGINS, B. B. 1927. Physiology and parasitism of *Sclerotium rolfsii*. Phytopath. 17.

14. HORSFALL, J. G. 1930. Combating damping-off of tomato by seed treatment. N.Y. (Geneva) Agr. Expt. Sta. Bull. 585.

15. ————. 1932. Dusting tomato seeds with copper sulphate. N.Y. (Geneva) Agr. Expt. Sta. Tech. Bull. 198.

16. ————. 1934. Zinc oxide as seed and soil treatment. N.Y. (Geneva) Agr. Expt. Sta. Bull. 650.

17. ————. 1934. Dusting with red copper oxide. N.Y. (Geneva) Agr. Expt. Sta. Bull. 643.

18. ————. 1935. Red oxide of copper as dust fungicide for combating damping-off by seed treatments. N.Y. (Geneva) Agr. Expt. Sta. Bull. 615.

19. MONTIETH, J. AND DAHL, A. S. 1928. Comparison of some strains of *Rhizoctonia* in cultures. J. Ag. Res. 36 : 897–903.

20. SHAW, F. J. F. 1912. Morphology and parasitism of *Rhizoctonia* sp. Mem. Dept. Agr. India Bot. Series. Vol. 5.

21. SMALL, T. 1928. *Rhizoctonia* foot rot of tomato. Ann. Appl. Biol. 14: 290–95.

22. SRIVASTAVA, H. C. 1949. Unpublished thesis on damping-off of tomato seedlings submitted to Agra University.

23. SUBRAMANIAM, L. S. 1919. A *Pythium* disease of ginger, tobacco and papaya Mem. Dept. Agr. India Bot. Series. Vol. 10.

24. TINT HOWARD. 1945. Studies in *Fusarium* damping-off of conifers. I. The comparative virulence of certain fusaria. Phytopath. 35: 421–39.

25. VAN HALTERN, F. 1935. Control of tomato seedbed diseases. Ga. Agr. Expt. Bull. 187.

26. WILSON, J. D. 1932. The use of formaldehyde dust in growing celery seedlings. Ohio Agr. Expt. Sta. Bimonth. Bull. 159.

27. ——— AND TILFORD, P. E. 1933. The use of formaldehyde dust in growing seedling. Ohio Agr. Expt. Sta. Bull. 520.

28. WRIGHT, E. 1945. Relation of micro-fungi and micro-organism of soil to damping-off of broad-leaf nurseries. J. Ag. Res. 70.

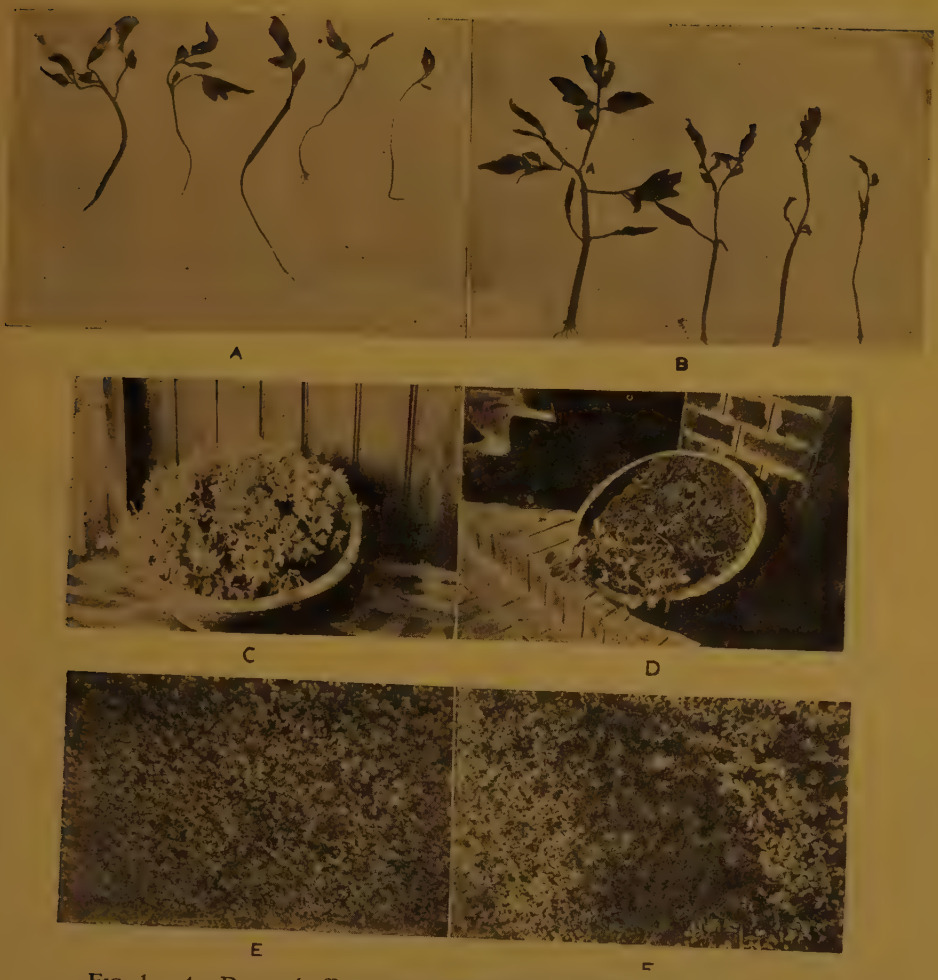

FIG. 1. *A*. Damped-off tomato seedlings, exhibiting base infection. *B*. Seedlings showing 'Top infection' and the advancement of the disease is downwards. *C* & *E*. Pot and bed showing healthy seedlings growing, where seeds were treated with Ceresan are sown in the soil treated with Formaldehyde dust. *D* & *F*. Pot and bed (check) where untreated seeds are sown in untreated soil.

THE PIGMENTS OF THE COROLLA OF *BRUGMANSIA AUREA* SAFF.*

By P. C. Joshi

Department of Botany, Government College, Ludhiana

(Received for publication on November 9, 1952)

Brugmansia aurea Saff. is a tree datura, native of the warmer parts of America. It bears periodic heavy blossoms of large funnel-shaped flowers with beautiful orange colour. It is grown as an ornamental plant in tropical gardens or inside the green-houses of the temperate regions. With *B. aurea* as the paternal parent and *Datura inoxia* Mill. as the maternal partner, the writer obtained an intergeneric hybrid by culturing the excised embryo *in vitro*. The cross otherwise always proved to be incompatible. The corollas of the flowers of both *D. inoxia* and the hybrid are almost pure white and they stand in sharp contrast to the deep orange colour of *B. aurea*. It was, therefore, thought desirable to investigate what pigments are responsible for the production of the orange colour in *B. aurea* and also to find out if any pigments in small ineffective amounts are present in the white corollas of *D. inoxia* or the hybrid. The present account deals with the investigation of the pigments of the corolla of *B. aurea*.

The young corolla of *B. aurea* while enclosed inside the calyx-tube is of green colour. As it emerges out of the calyx, it turns greenish yellow. Gradually, the green shade disappears and by the time the corolla unfolds, its colour changes to bright yellow. Later on, the limb starts turning orange, from the tip backwards. In the fully mature corolla, the limb is deep orange with prominent green veins and the tube is yellowish green.

Investigation

The fresh young green corolla and the orange part of the mature corolla were separately crushed and shaken with various solvents. It was found that the colouring matter was insoluble in water or dilute acid (1% HCl). It was more or less soluble in the various organic solvents, like chloroform, acetone, benzene, ethyl alcohol, ethyl ether, etc., known to dissolve plastid pigments. The young green corolla yielded a green solution with red flourescence, while the orange parts gave a deep yellow extract. This indicated the absence of the sap soluble pigments belonging to the groups of anthoxanthins and antho-

* The article is a portion of the thesis written under the direction of Dr. A. F. Blakeslee, Director, Genetics Experiment Station, Smith College, U.S.A., and submitted to the faculty of Smith College in partial fulfilment of the requirements for the Degree of Doctor of Philosophy. The writer is deeply indebted to Dr. Blakeslee and Dr. S. Satina for the guidance and other help rendered during the investigation.

cyanins, and the possible presence of plastid pigments. The green 80% aqueous acetone extract of the young green corolla was subjected to the procedure for the separation of the chlorophyll and carotenoid components, based on their differential solubility in the various organic solvents as described by Haas and Hill (1928). After transferring the colouring matter to ethyl ether, a strong methyl alcoholic solution of caustic potash was added. A transient brown colour was produced at the junction of the two liquids. The colour gradually changed to olive-green and finally back to the original green, giving a positive 'Phase Test' for the presence of chlorophylls. After adding a little water to this liquid and shaking it, two layers separated out, the lower green aqueous containing chlorophylls and the upper yellow ethereal the carotenoid matter. The yellow ethereal layer solution, after being washed properly, was concentrated by evaporation. Later it was diluted with light petroleum and shaken up with 90% methyl alcohol. Both the petrol ether and the methyl alcohol layers showed the presence of the yellow colouring matters. This strongly indicated the presence of both carotin and xanthophyll besides the chlorophylls in the green corolla. A similar treatment of the acetone extract of the orange part of the mature corolla yielded no green layer and gave a negative 'Phase Test' for the presence of chlorophylls while it displayed yellow pigments in both petrol ether and methyl alcohol layers. This showed that in the young green corolla, the chlorophylls and the carotenoids, carotin and xanthophyll, are present. As the corolla matures and turns orange, the chlorophylls disappear leaving behind carotenoids.

For confirmation of the above results, chromatography, an ingenius analytical method discovered by Tswett (1910) and elaborated by several other workers (cited by Zechmeister and Cholnoky, 1944; Strain, 1942) was resorted to. Chromatography enables one to separate out many biological compounds of closely related chemical structure. The separation depends on the property of their being selectively adsorbed to different degrees by the various adsorbents. It is observed that if an extract of the green colouring matter of the higher plants is slowly percolated through an adsorption column made up of the layers of, from above downwards, sugar, calcium carbonate and aluminium oxide, the chlorophylls are held by sugar, xanthophyll by calcium carbonate and carotin by alumina (Harrow, 1944). The writer adopted the following procedure for the chromatographic analysis of the pigments of the corolla of *B. aurea*. In each case 200 gm. of the fresh corolla was crushed and then immersed in a mixture of 45 c.c. petroleum ether (B.P. 70° C.), 5 c.c. benzene and 15 c.c. methyl alcohol for about four hours. The filtrate was transferred to a separatory funnel and the methanol was removed by carefully washing with distilled water. After that the pigment extract was shaken with some anhydrous sodium sulphate to eliminate the traces of water. For the adsorption column a 20 cm. long and 1 cm. wide glass tube, with a constriction at the lower end was employed. A little cotton wool was inserted into the constriction. A uniform, moderately pressed, adsorption column was prepared as follows: lower 4 cm. aluminium oxide (activated by heating at 200° C. for 15 minutes), middle 4 cm. calcium carbonate

(activated by heating at 150° C. for 10 minutes), upper 6 cm. finely powdered dry sucrose covered over with some anhydrous sodium sulphate. The column was made wet with petroleum ether (B.P. 70° C.), run down from a dropping funnel through gentle suction. This was followed by slow percolation of the extract of the corolla through the adsorbent column and afterwards washing it down with a little petroleum ether (B.P. 30–50° C.). Throughout precaution was taken to keep the column at the top constantly covered with a liquid. After the proper development of the chromatogram, the column was sucked dry in a stream of nitrogen. The size and the intensity of the colour of the various pigment bands formed in the different parts of the column were noted. The chromatogram obtained from the extract of the young green corolla showed four distinct bands—two green ones in the sugar layer, a light yellow in the calcium carbonate layer and a reddish one in the aluminium oxide layer. It confirmed the earlier results that in the young stage the corolla contains the usual four pigments of the green parts of the plants—the two chlorophylls, xanthophyll and carotin. After its emergence out of the calyx tube, the bright yellow corolla on chromatography exhibited the presence of the two carotenoids in larger amounts and the complete absence of the chlorophylls. The chromatogram of the extract of the orange part of the fully mature corolla also showed complete absence of the chlorophyll pigments, but it displayed a still greater increase in the red carotenoid content while the xanthophyll amount remained almost the same.

The histological examination of the corolla of *B. aurea* revealed that the pigments are contained inside the epidermal cells only. Extremely small chromatophores could be seen in the epidermal layer of the young green corolla while it was still inside the calyx tube. No plastids, however, could be made out after the corolla emerged out of the calyx and turned yellow. In the epidermal cells of the yellow corolla the carotenoid pigments are seen under the microscope as shiny and oily looking yellow substance, diffused in the cytoplasmic matrix. It leads to the conclusion that the green plastids of the young corolla distintegrate during its later growth setting free the pigments in the cytoplasm. The chlorophylls disappear leaving behind the carotenoids which impart a yellow colour to the organ. The cells of the epidermis of the orange part of the mature corolla, however, showed the presence of numerous fine acicular red crystals besides the diffused yellow substance in the cytoplasm. These crystals are, presumably, of carotin, or some of its isomer, like lycopin or some other allied carotenoid, into which carotin may be easily convertible. The chromatogram of the extract of the corolla at this stage displayed a marked increase in the red carotenoid contents. The appearance of the orange colour of the corolla of *B. aurea*, therefore, results out of the combined effect of the large number of the red crystals and the yellow diffused pigment occurring together in its epidermal cells. The orange colour of the petals of *Trapæolum majus* and several other plants has been reported to be a somewhat similar combined effect of the presence of yellow and red materials in the tissues (Möbius, 1937). The petals of *Trapæolum*

majus, however, contain a red sap and yellow chromatophores in the same cells.

Summary

Brugmansia aurea Saff. is a tree datura, native of the warmer parts of America. The young corolla while enclosed inside the calyx tube is of green colour. Later it gradually turns greenish yellow, yellow, and finally orange. By determining the differential solubility of its pigments in various organic solvents and by the method of chromatographic analysis, it has been found that the young green corolla contains the typical pigments of a green-leaf chlorophylls, xanthophyll and carotin. Later on, the chlorophylls disappear while the carotenoids increase in amount. The mature corolla shows the presence of large amounts of carotenoids inside the epidermal cells in the form of diffused yellow pigment and numerous red needle-like crystals. The combined effect of the yellow and red results in orange colour of the corolla.

Literature Cited

1. Harrow, B. *et al.* 1944. Laboratory Manual of Biochemistry. 2nd Ed. Philadelphia.
2. Haas, P. and Hill, T. G. 1928. An Introduction to the Chemistry of Plant Products. 4th Ed. London.
3. Möbius, M. 1937. Pigmentation in Plants, exclusive of Algæ. Bot. Rev. 3: 351–363.
4. Strain, H. H. 1942. Chromatographic Adsorption Analysis. New York.
5. Tswett, M. 1910. Chlorophylls in Plant and Animal World (*Chromofilli restitelnom i schivotnom* Mirje). Warschau: Tipogr. Warshawskago utschebnago Okruga.
6. Zechmeister, L. and Cholnoky, L. 1944. Principles and Practice of Chromatography (Eng. Transl.). New York.

FLORAL ANATOMY AND EMBRYOLOGY OF TWO SPECIES OF *ELÆOCARPUS*

By C. Venkata Rao

Department of Botany, Andhra University, Waltair

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In a previous paper, the writer (1952) described the life-history of *Muntingia calabura* L. belonging to Elæocarpaceæ, and summarised the observations of Mauritzon (1934) on the embryology of 2 species of *Aristotelia*. In another paper (Rao, 1952 *a*), the floral anatomy of *Muntingia calabura* was described. The present paper deals with the floral anatomy, structure of the anther and ovule, and the development of the gametophytes in 2 species of *Elæocarpus*, namely *E. robustus* Roxb. and *E. ganitrus* Roxb. The material of the first was sent by Mr. R. Seshagiri Rao from the Indian Botanic Garden, Calcutta, and that of the second by Mr. V. V. Apte from Poona. It was fixed in formalin-acetic-alcohol in both the cases. Customary methods of dehydration and infiltration were followed and Delafield's hæmatoxylin and a combination of safranin and fast green were used as stains.

Flowers

The flowers of both species are provided with a pentamerous polyphyllous valvate perianth. There is a gynandrophore with 5 antisepalous cushion-shaped nectaries, which are particularly prominent in the open flowers of *E. robustus*. The petals show the characteristic laciniate apex. There are 45 free stamens in 2 series: the outer of 5 antipetalous groups of 8 each and the inner of 5 antisepalous stamens. The filaments and anthers are ciliary throughout their length. In *E. ganitrus*, the anther terminates in 2 elongated bristles. The ovary in this species is 5-carpellary, while it is tricarpellary in *E. robustus*. There are 4–6 ovules in each loculus on axile placentæ in *E. ganitrus* and 2 pendulous ovules in a loculus in *E. robustus*; the style is 5- and 3-lobed respectively.

Anatomy of the Flowers

The pedicel in *E. robustus* shows a ring of 5 small bundles alternating with 5 larger bundles (Fig. 13). The former function as sepal traces. In *E. ganitrus*, on the other hand, the vascular bundles in the pedicel are more numerous and of the same size (Fig. 1). At the base of the thalasa , 5 sepaline traces are given off. In *E. robustus*, each trace first gives off two strands laterally which function as the marginals for the petals (Fig. 14), while the main part of it enters the base of the sepal where it divides to form the midrib and laterals (Figs. 14 and 15). In *E. ganitrus*, on the other hand, each sepal trace splits radially into two bundles (Fig. 2) from each of which a number of branches are given off. These function as petal commissurals and

FIGS. 1–12

FIGS. 1–12. Floral anatomy of *Elæocarpus ganitrus*.—Fig. 1. The stele of the pedicel showing origin of sepal traces. Fig. 2. Sepal traces dividing to form petal marginals. Fig. 3. T. S. of the base of a bud showing sepals, petal marginals and origin of conjoint petal-stamen traces. Fig. 4. Emergence of conjoint petal-stamen traces. Fig. 5. Formation of outer staminal traces; the bases of the petals are seen on the outside. Fig. 6. Chorosis of the outer staminal traces to form staminal bundles and the origin of inner staminal traces. Fig. 7. Emergence of antipetalous and antisepalous staminal traces. Fig. 8. Origin of dorsal carpellary traces. Fig. 9. A part of the anther showing thick-walled epidermal and sub-epidermal cells, tapetum and pollen grains. Fig. 10. T. S. of a flower bud showing sepals, petals which enfold the filaments of antipetalous groups of stamens, filaments of antisepalous stamens and ovary. Fig. 11. T. S. of the ovary showing dorsal and ventral carpellary bundles. Fig. 12. T. S. of the style showing stylar canal and 5 vascular bundles. Fig. 9, ×235; Fig. 11, ×50; the rest, ×10.

sepal laterals (Fig. 3). The two bundles again fuse and form the sepal midrib. In *E. robustus*, the 5 large bundles which remain after the emergence of the sepal traces undergo a radial splitting and increase in number (Fig. 14). Now, alternating with the sepaline traces 5 conjoint petal-stamen traces are given off (Figs. 3, 4 and 15). In *E. ganitrus*, each trace splits in a horizontal plane; the lower branch forms the midrib bundle of the petal, while the upper one supplies the stamens. The latter splits first into 2 or 3 large bundles and then by secondary chorosis, forms 8 bundles (Figs. 5 and 6). These pass into the filaments of the antipetalous groups of stamens which are clasped by the infolded petal margins (Figs. 10 and 19). In *E. robustus*, no splitting occurs at this level; the median part of the trace enters the petal base (Fig. 15) and all along its 2 margins are organised groups of 4 bundles (Fig. 16). So the 8 staminal bundles in this species stand in 2 antipetalous rows before passing into the stamens (Fig. 16). Next, 5 traces are given off from the receptacular stele, on sepal radii (Figs. 6 and 7). Each trace in *E. ganitrus*, gives off 2 lateral strands which fade out in the nectary through which the trace passes, while the median bundle enters the filament of the antisepalous stamen (Fig. 8). The branching into 3 strands is strongly suggestive of the 3-bundled trace of Sterculiaceæ (Rao, 1952 *a*). In *E. robustus*, the trace courses in an oblique manner through the thick cushion-shaped nectary without branching and passes into the filament of the inner series of stamens (Fig. 18). The nectary in this species is fed by strands given off from neighbouring staminal bundles of the outer series (Figs. 16 and 17).

At the base of the ovary, the stele becomes 5-angled in *E. ganitrus* and 3-angled in *E. robustus* and from each angle is given off the dorsal carpellary trace (Figs. 8 and 18). So in *E. ganitrus* the flower is typically pentamerous and the loculi are antipetalous. Occasionally, however, 4-merous and 6-merous flowers are met with. After the emergence of the dorsal carpellary traces, the stele breaks up into 10 or 6 ventral bundles. The 2 bundles situated at the base of the septum fuse and form the common bundle (Figs. 11 and 21) from which the ovular traces are given off. Towards the top of the ovary, the 3 bundles of each carpel fuse again and the resultant strand runs along one of the lobes of the style (Figs. 12 and 22). At about the middle of the ovary, an axial space appears, which extends up to the base of the style. The


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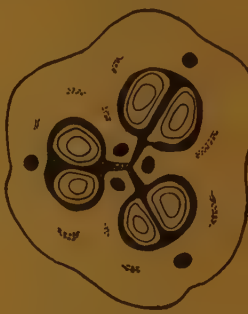
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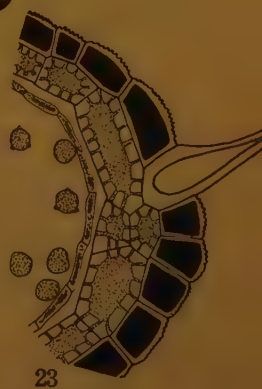
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FIGS. 13–23

FIGS. 13–23. Floral anatomy of *Elæocarpus robustus*. Fig. 13. Stele of pedicel showing origin of sepal traces. Fig. 14. The origin, emergence and division of the sepal traces. Fig. 15. The origin and emergence of the conjoint petal-stamen traces. Fig. 16. Organisation of groups of antipetalous staminal bundles; bases of petals seen to the outside; note that vascular strands are given off from the staminal bundles to feed the lobes of the disc. Fig. 17. Emergence of staminal bundles and the origin of antisepalous staminal traces. Fig. 18. Emergence of antisepalous staminal traces through the nectaries and the origin of dorsal carpellary traces. Fig. 19. T. S. of a flower bud showing sepals, infolded petals which enclose groups of stamens, filaments of antisepalous stamens and ovary. Fig. 20. T. S. of a flower bud at a higher level; note the laciniate apex of the petals. Fig. 21. T. S. of the ovary showing dorsal and ventral carpellary bundles. Fig. 22. T. S. of the style. Fig. 23. Portion of the anther wall showing epidermal cells, with striated cuticle, subepidermal layer of stone cells, degenerating tapetum and pollen grains. Fig. 21, ×30; Fig. 22, ×90; Fig. 23, ×235; the rest, ×10.

ovary and nectaries are closely beset with stiff unicellular hairs. The cells of the epidermis of the anther and style are filled with deep staining tannin contents (Figs. 9, 22 and 23).

The above study shows that the flowers of both species of *Elaeocarpus* are pentacyclic. They resemble the flowers of other Malvales in the origin, emergence and behaviour of the conjoint petal-stamen traces. Of the 2 whorls of staminal traces, the outer series undergoes primary and secondary chorosis and forms the major number of staminal bundles, while the inner passes directly into the filaments of the antisepalous stamens. The method of chorosis of the outer staminal traces and the branching of the inner staminal traces into 3 bundles each in *E. ganitrus*, strongly suggest that the traces in this genus are also 3-bundled as in Tiliaceæ and Sterculiaceæ. The occurrence of pentacyclic flowers in this genus shows that it is more primitive than genera of Tiliaceæ like *Corchorus* and *Triumfetta* which were found to be tetracyclic due to the suppression of the inner whorl of stamens (Rao, 1952 *a*). This conclusion agrees with that of Kukachka and Rees (1943) on the basis of their studies of wood anatomy.

MICROSPOROGENESIS AND MALE GAMETOPHYTE

The primary archesporium in each anther-lobe consists of 1 or 2 rows of hypodermal cells. These cells by periclinal division form the primary parietal cells to the outside and the primary sporogenous cells to the inside. By anticlinal and periclinal divisions the former give rise to 4-5 layers of wall cells below the epidermis (Fig. 24). Early in development, some of the epidermal cells of the anther grow into spinescent structures and the rest accumulate tannin in their lumens. Hence they stain deeply (Fig. 24). The cuticle of the epidermis is ridged (Figs. 25 and 26). The cells of the sub-epidermal layer develop into stone cells which show thick wall and prominent pitting, which is especially pronounced in *E. robustus* (Fig. 23). Fibrous thickenings are not developed on their walls. The innermost wall layer develops into a tapetum of the secretory type. The cells become binucleate during the prophase I of the pollen mother cells and remain so till they degenerate. The remnants of the tapetal cells persist even in anthers

FIGS. 24–39

FIGS. 24–39. Development of anther and ovule in *Elæocarpus*.—Fig. 24. T. S. of an anther lobe of *Elæocarpus robustus* showing microspore mother cells and organisation of tapetum; note the tannin-filled epidermal cells, ×430. Fig. 25. T. S. of an anther of *E. robustus* showing the two layers of regularly placed cells between which dehiscence occurs, ×130. Fig. 26. An anther lobe of *E. ganitrus*, ×115. Figs. 27 & 28. Anthers of *E. robustus* with degenerate loculi, ×340. Figs. 29 & 30. An abnormal pollen grain and a pollen tetrad of *E. robustus*, ×1,800. Figs. 31 & 32. Dehiscing anthers of *E. ganitrus* and *E. robustus* respectively, ×200. Figs. 33 & 34. Tetrahedral tetrad of pollen grains and a mature pollen grain, ×1,800. Figs. 35–39. Various stages in development of the ovule in *E. robustus*. Fig. 35, ×500; Fig. 36, ×115; Figs. 37 & 38, ×140; Fig. 39, ×75.

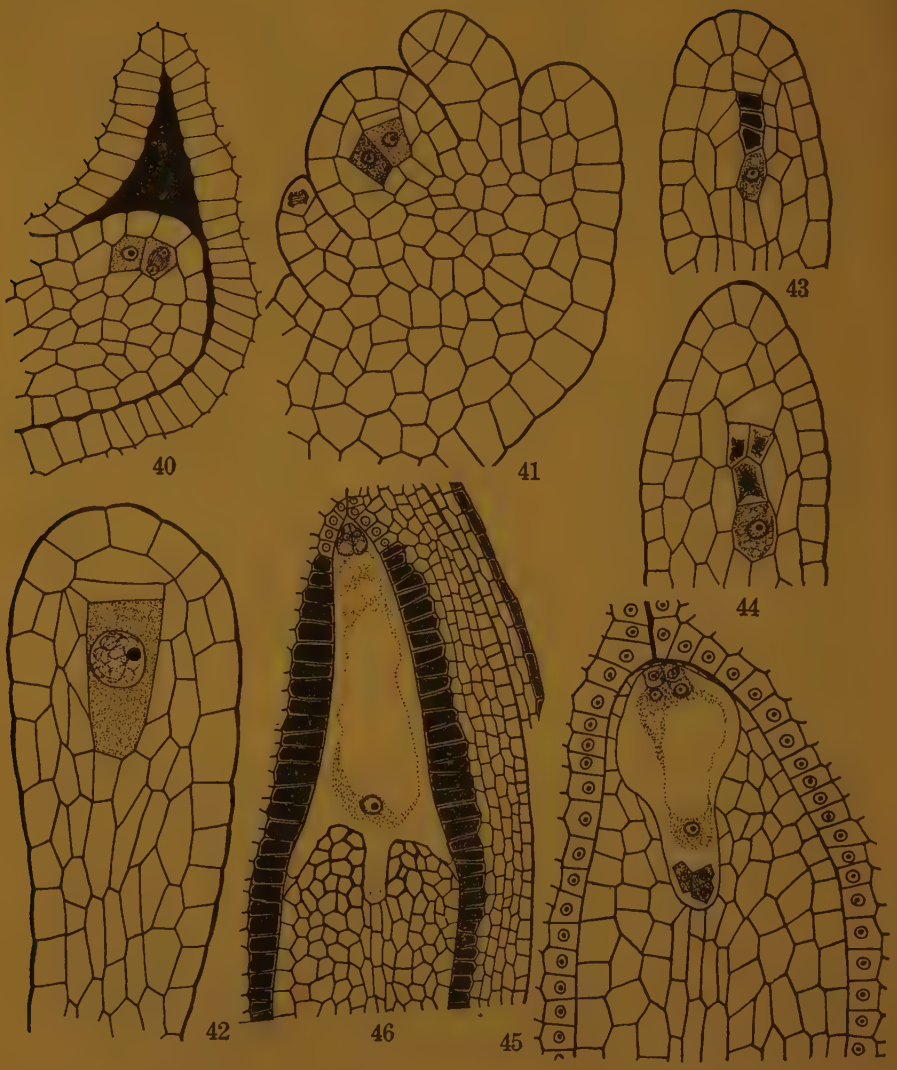
with mature pollen grains (Fig. 25). The median wall layers get ultimately crushed. Dehiscence of the anthers is brought about by a longitudinal cleft in the apical region (Figs. 31 and 32). This occurs between 2 rows of thin-walled cells organised in the connective just by the side of the vascular bundle (Fig. 25). The 4 loculi of the anther do not coalesce in pairs in the mature anther. After the dehiscence of the anther into 2 longitudinal halves, each loculus opens to the outside separately and liberates the pollen grains.

There is a marked secondary increase in the number of microsporocytes; 30–35 are seen in a T.S. and about 100 in a row in a L.S. of an anther lobe. The microspore tetrads are tetrahedral (Fig. 34) and cytokinesis occurs by furrowing. The young microspore tetrad is invested by a sheath of callose for some time. The pollen grains are very small, measuring only 8–10 μ in diameter. They are smooth-walled, spherical and triporate. The germ pore is situated at the summit of a small papillate projection of the exine and the intine slightly protrudes through it. The pollen grains are shed in the 2-nucleate stage (Fig. 34).

Occasionally, however, cases are noticed in which all the pollen grains of an anther loculus become relatively very large and measure 15–20 μ in diameter; sometimes they fail to separate from the tetrads. The exine becomes proportionately thick. The cytoplasm is relatively scanty and the nucleus looks hypertrophied (Figs. 29 and 30). A few of the microsporocytes usually degenerate in all anthers. Occasionally, however, all the sporogenous cells undergo degeneration either in one or more or all the 4 loculi of an anther. In such cases the loculi do not develop and the anther wall contains fewer layers, as the tapetum and the sub-epidermal layer of stone cells do not develop (Figs. 27 and 28).

THE OVULE

The ovules in both the species are anatropous, bitegmic and crassinucellate. In *E. robustus*, they are pendulous and the micropyle faces the top of the loculus. In *E. ganitrus*, the ovules in the lower tier are pendulous but those of the upper tier get tilted due to the growth of the lower and usually stand inclined (Fig. 47) or even transversely to the ovarian axis. The outer integument is 3-layered except in the region of the micropyle where it is thicker, and the inner is 5–6 layered. The former grows faster and forms the micropyle even before the megaspore mother cell has divided (Fig. 36). In the fertilisable ovule, the mircopyle has a zigzag form characteristic of the Malvales (Fig. 39). The



FIGS. 40–46

FIGS. 40–46. *Elæocarpus robustus*.—Fig. 40. L. S. of a loculus of ovary showing ovule primordium with 2 functional archesporial cells. Fig. 41. Ovule primordium with developing integuments and two functional megaspore mother cells. Fig. 42. Nucellus with full grown megaspore mother cell. Figs. 43 & 44. Nucelli with linear and T-shaped tetrads respectively. Fig. 45. Nucellus with young embryo sac; note that the cell walls are organised earlier around the antipodals; the inner epidermal cells of the inner integument are becoming radially elongated. Fig. 46. Part of an ovule showing fully formed embryo sac; note the endothelium-like cells of the inner integument. Fig. 42, ×690; Fig. 46, × 225; the rest, ×500.

ovule has a fusiform shape due to the development of a hump-like chalazal outgrowth (Fig. 39). After the 8-nucleate stage of the embryo sac, the cells of the inner epidermis of the inner integument become radially elongated and accumulate deep staining contents. They resemble the endothelium in shape and may function in the nutrition of the embryo sac which at this stage borders on them. The cells of the outer epidermis of the outer integument also accumulate deep staining contents (Fig. 39).

The nucellus is straight and massive. The parietal tissue is not as extensive as in *Aristotelia* species (Mauritzon, 1934). Its maximum thickness of 3–4 layers, is attained at about the tetrad stage of the ovule (Fig. 44). No nucellar cap is formed but some cells of the nucellar epidermis may undergo a periclinal division. The entire nucellus above and on the sides of the embryo sac is crushed in the fertilisable ovule and the sac borders on the inner epidermis of the inner integument as in the case of *Aristotelia* species. In the latter, this condition is attained only after fertilisation, but it is reached in *Elæocarpus* even before fertilisation. The nucellus below the embryo sac is extensive. A socket of thick-walled cells surrounds the antipodal end of the sac, due to which it remains narrow in this part. A hypostase of elongated narrow cells connects the lower end of the embryo sac with the vascular bundle in the chalaza (Figs. 54 and 55).

Megasporogenesis and Embryo Sac

In *E. robustus*, the ovule primordia show an early curvature. They nearly fill the loculus which is lined by radially elongated richly protoplasmic cells (Fig. 40). The primary archesporium is multicellular in origin and differentiates even before the integument primorida are demarcated. Usually only one cell functions and the rest merge into the nucellus. Two collaterally placed functional cells are occasionally met with in the early stages (Figs. 40 and 41). The cutting off of the primary parietal cell synchronises with the demarcation of the integument primordia.

A full grown megaspore mother cell has an elongated and tapering form, with its nucleus situated near the broad micropylar end (Figs. 42 and 48). As division occurs in this position, the cells of the dyad and tetrad are markedly different in size and shape, the lowest cell being elongated and tapering. Megaspore tetrads are usually linear, but a few T-shaped tetrads are noticed in *E. robustus* (Fig. 44). The chalazal megaspore forms the 8-nucleate embryo sac.

Enlargement of the embryo sac is slow in the intial stages. At the early 8-nucleate stage, it has an ovoid shape (Fig. 45) and measures about 55 μ in length in *E. robustus*. Cell walls are organised earlier around the antipodals. Later, there is a sudden and rapid enlargement of the sac due to which all the nucellus cells above and at the sides are crushed. The antipodal end remains narrow due to its being invested by thick-walled cells. The mature embryo sac has a sagittate appearance in L.S. (Figs. 46 and 54). The cells of the egg apparatus

FIGS. 47-56

FIGS. 47–56. *Elæocarpus ganitrus*.—Fig. 47. L. S. of a loculus of the ovary showing the position of ovules, ×50. Fig. 48. Nucellus with full-grown megaspore mother cell, ×500. Fig. 49. Megaspore mother cell in meiosis I, ×500. Fig. 50. Ovule showing full-grown megaspore mother cell; note that the outer integument has already formed the micropyle, ×140. Fig. 51. Nucellus with a linear tetrad of megaspores, ×500. Fig. 52. Ovule with fully formed embryo sac; note the air space between the integuments and the hypostase, ×90. Fig. 53. An ovule in which all the megaspores have degenerated, ×90. Fig. 54. Nucellus with the full grown embryo sac; note endothelium-like inner epidermis of inner integument, ×285. Fig. 55. Lower part of nucellus showing hypostase, ×285. Fig. 56. Egg apparatus; note starch grains in the cytoplasm of the embryo sac, ×715.

are equal in size and the synergids show small lateral hooks (Fig. 56). The polar nuclei meet at the mouth of the constricted part of the embryo sac and fuse there (Figs. 39 and 55). By this time the antipodals degenerate. Relative to the size of the sac the cytoplasm looks scanty. It contains a few starch grains (Fig. 54). The mature embryo sac of *E. robustus* measures 225 μ in length and 75 μ in width at the widest part.

Sometimes ovules were noticed in which all the megaspores had degenerated completely, and hence no embryo sacs were formed (Fig. 53). Since degeneration of the megaspores did not result in an immediate degeneration of the ovules, such ovules occurred alongside with normal fertilisable ones.

DISCUSSION

The family Elæocarpaceæ occupies a peculiar taxonomic position. Hutchinson (1926) and Rendle (1938) amalgamate the component genera in Tiliaceæ and do not give them even the rank of a tribe. Bentham and Hooker (1862–83) and Edlin (1935) treat it as a tribe of Tiliaceæ. Metcalfe and Chalk (1950) consider that the anatomical features of its members are so distinct from those of the rest of Malvales as to justify their being treated as a separate family. Engler and Prantl (1895) attached so much importance to these anatomical differences that they raised the family to the status of a separate sub-order Elæocarpineæ, placing all the other families except Chlænaceæ and Scytopetalaceæ in another sub-order, the Malvineæ.

Species of *Elæocarpus* resemble *Muntingia calabura* (Rao, 1952) in secondary increase in microspore mother cells, anther tapetum of the secretory type, and small, spherical, smooth-walled triporate pollen grains. The method of dehiscence of the anther, however, is different in the two: in *Muntingia* it is brought about by fibrous endothecium while in *Elæocarpus* it is effected by a longitudinal terminal cleft. The ovules in these 2 genera resemble those of *Aristotelia* (Mauritzon, 1934), in being anatropous, bitegmic and crassinucellate. The shape of the embryo sac and its aggressive enlargement which results in crushing out the whole of the nucellus above it, are closely similar in *Elæocarpus* and *Aristotelia*. A hypostase is found in *Muntingia* and *Elæocarpus*. In most of the above characters, Elæocarpaceæ resembles Tiliaceæ which indicates that its position in any taxonomic

grouping of the families should be nearest to Tiliaceæ. Separation of the 2 families and grouping of Tiliaceæ along with Malvaceæ in another sub-order as proposed by Engler and Prantl (1895), not only obscures the affinities between the 2 families but makes Malvineæ a heterogeneous group. Malvaceæ stands out distinctly from the rest of Malvales both in the habit of the plants as well as embryological features like 2-locular anthers, functioning of sporogenous cells directly as microsporocytes, plasmodial anther tapetum, multiporate, spinescent pollen grains, campylotropous ovules and curved embryo sacs. So the grouping of the families on the lines suggested by Hutchinson (1926) seems to accord best with the embryological evidence, though a complete splitting of the order into 2 as he has done seems unwarranted in view of the homogeneity of the order.

Summary

The floral anatomy, structure of the anther and ovule and development of the gametophytes have been studied in *Elæocarpus ganitrus* Roxb. and *E. robustus* Roxb.

The flowers in both species are pentacyclic. The petal marginals are derived from sepal traces. The petals and outer whorl of stamens have conjoint traces. After separation, the staminal traces undergo primary and secondary chorosis and give rise to groups of 8 staminal bundles. The inner staminal traces proceed directly into the antisepalous stamens. The nectaries are fed by strands given off from staminal bundles.

The anther wall is 5–6 layered. Some of the cells of the epidermis develop into spinescent structures and others accumulate tannin. The cells of the sub-epidermal layer, instead of showing fibrous thickenings, develop into stone cells with thick walls and prominent pits. The innermost layer develops into the tapetum of secretory type. The anthers open by a terminal longitudinal cleft which occurs between 2 layers of thin-walled regularly arranged cells of the connective. The mature pollen grains are 2-nucleate, spherical, smooth walled and triporate; the intine protrudes slightly through the germ pores.

Large degenerating pollen grains and anthers in which one or more loculi have not developed due to the early and complete degeneration of the microspore mother cells are occasionally observed.

The ovules are anatropous, bitegmic and crassinucellate with a zigzag micropyle formed by both the integuments. There is usually only one functional archesporial cell which cuts off a primary wall cell. Megaspore tetrads are usually linear and the chalazal megaspore forms the 8-nucleate embryo sac. The embryo sac expands aggressively and crushes all the nucellus in the upper part of the ovule and borders on the radially elongated endothelium-like cells of the inner integument. The synergids are slightly hooked. The polar nuclei fuse at about the middle of the sac before fertilisation. The antipodals degenerate completely by this time. A few starch grains are found in the cytoplasm of the mature embryo sac. A hypostase

of narrow elongated cells connects the tubular antipodal end of the embryo sac with the vascular bundle which ends in the chalaza.

Acknowledgements

The writer wishes to express his grateful thanks to Prof. A. C. Joshi and Prof. J. Venkateswarlu for their kind interest in the work. His thanks are also due to Mr. R. Seshagiri Rao and Mr. V. V. Apte for the materials of *Elæocarpus robustus* and *E. ganitrus* respectively.

Literature Cited

Bentham, G. and Hooker, J. D. 1862–83. Genera Plantarum. London.

Edlin, H. L. 1935. A critical revision of certain taxonomic groups of the Malvales. New Phyt. 34: 1–20 and 122–143.

Engler, A. and Prantl, K. 1895. Naturalichen Pflanzenfamilien. Leipzig.

Hutchinson, J. 1926. Families of Flowering Plants. Vol. I. London.

Kukachka, B. F. and Rees, L. W. 1943. Systematic anatomy of the woods of the Tiliaceæ. Tech. Bull. Minn. Agric. Expt. Sta. 158: 1–70.

Mauritzon, J. 1934. Zur Embryologie der Elæocarpaceæ. Ark. Bot. 26: 1–8.

Metcalfe, C. R. and Chalk, L. 1950. Anatomy of Dicotyledons. Vol. I. London.

Rao, C. V. 1952. The embryology of *Muntingia calabura* L. J. Indian bot. Soc. 31: 87–101.

————. 1952 *a*. Floral anatomy of some Malvales and its bearing on the affinities of the families included in the order. J. Indian bot. Soc. 31: 171–203.

Rendle, A. B. 1938. Classification of Flowering Plants. Vol. II. London.

A REVISION OF THE INDO-MALAYAN SPECIES OF *CHONEMORPHA* G. DON

By R. Seshagiri Rao

The Herbarium, Indian Botanic Garden, Calcutta

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The genus *Chonemorpha* G. Don has been recently revised by Chatterjee in *Kew Bulletin* (1947: 47–52). In his account, Chatterjee has raised some doubts regarding the real identity of *C. assamensis* as the original description of this species was very inadequate. The present paper on the same subject is intended to supplement Chatterjee's recent account and contains a description of a new species besides clarification of a few nomenclatural points.

The genus is mainly confined to the tropical and sub-tropical zones of India, Burma, Malay Peninsula, Malayan Archipelago, Siam, Annam and China. There are 14 species recorded so far, of which India and Burma claim 5 species, Malayan Archipelago 3, Siam 3, Annam 6 and S.W. China 4 species (Map Fig. 1).

Fig. 1. Map of India and S.-E. Asia showing the Distribution of the Genus *Chonemorpha*.

- ● *C. fragrans* (Moon) Alston
- \+ *C. assamensis* Furtado
- ○ *C. blancoi* Merrill
- ■ *C. griffithii* Hook. f.
- □ *C. penangensis* Ridley
- △ *C. valvata* Chatterjee
- ✱ *C. pedicellata* Seshagiri Rao

1 *C. eriostylis* Pitard
2 *C. graciliflora* Pitard
3 *C. grandeareana* Pierre ex Spire
4 *C. macrantha* Pitard
5 *C. megacalyx* Pierre
6 *C. splendens* Chun et Tsiang
7 *C. yersini* Vernet ex Spire

With a view to elucidate the systematic position of some of the species already published, a modified key with some additional notes on the species is given. A new species collected from India has also been described.

KEY TO THE INDO-MALAYAN SPECIES OF *Chonemorpha*

A. Calyx with a clear tube:
  B. Calyx finely pubescent:
    C. Calyx 10–12 mm. long with very short teeth-like lobes; slightly contracted at apex; corolla tube 2·5–3 cm., Pedicels 1½–2 cm. long ... . *C. penangensis* (5)
    C. Calyx 12–15 mm. long with long conical lobes about ⅓ the length of Calyx; Corolla tube 4·5 cm.; Pedicels very long 3·5–5 cm. .. .. .. *C. pedicellata* (7)
  B. Calyx glabrous or glabrescent:
    D. Calyx 9–12 mm. long with broad lobes, ½–⅓ the length of Calyx:
      E. Corolla tube 3·5–4·5 cm.; leaves with round or slightly cordate base; petiole short not more than 3 cm. .. *C. fragrans* (1)
      E. Corolla tube 2–2·5 cm.; leaves with distinct cordate base; Petiole very long 6–8 cm. .. *C. blancoi* (3)
    D. Calyx 4–5 mm. long, crateri-form with broad lobes nearly ½ the length of Calyx .. *C. assamensis* (2)

A. Calyx without a tube, deeply five-partite:
    F. Calyx lobes imbricate; plant, a climber with smaller leaves *C. griffithii* (4)
    F. Calyx lobes valvate; Plant, a shrub with slightly bigger leaves .. *C. valvata* (6)

ENUMERATION

1. **Chonemorpha fragrans** (Moon) Alston in *Ann. Roy. Bot. Gard., Perad.*, **11**: 203 (1929); in Trimen *Fl. Ceyl.*, **6**: 192 (1931); Furtado in *Gard. Bull. Str. Settlements*, **9**: 115 (1935); Alston in *Kandy Fl.*, 47 (1938); Chatterjee in *Kew Bull.*, **1948**: 68 (1948); *Echites fragrans* Moon Cat., 20 (1824); Type species; "*Belutta-kaka-kodi*" Rheede, *Hort. Malab.*, **9**: 7, tabs. 5 and 6 (1689) (Type of *E. fragrans* Moon); *Echites macrophylla* Roxb., *Hort. Beng.*, 20 (1814) *nomem nudum. et Fl. Ind.*, **2**: 13 (1832); *Wall. Cat.* 1657 A, B. (non *E. macrophylla* H.B.K., *Nov. Gen. et. Spec.*, **3**: 219 (1819). This is entirely a different plant as pointed out by Chatterjee (*l.c.* 50); *E. grandis* Wall. Cat. 1658 *nom. nud.*; *E. latifolia Wall. Cat.*, 1657, 1657 E *nom. nud.*; *E. elegans* Wall. Cat. 1656 *nom. nud.*; *Chonemorpha macrophylla* (Roxb.) G. Don in *Gen. Syst.*, **4**: 76 (1838); Wight, *Icones Pl. Ind. Or.* tab. 432 (1843); *DC., Prodr.*, **8**: 430 (1844); Miquel, *Fl. Ind. Bat.*, **2**: 444 (1856); Thwaites, *Enum.* 194 (1864); Hook. f., *Fl. Br. Ind.*, **3**: 661 (1882); Trimen, *Fl. Ceyl.*, **3**: 138 (1895); Hook. f., *Bot. Mag.* tab. 7492 (1896); Gamble in King's *Mat. Fl. Mal. Pen*, **4**: 693 (1907); Ridley in *Jour. Roy. As. Soc. Str. Br.*, **57**: 68 (1910); Gamble, *Fl. Mad.*, 818 (1923); Furtado in *Gard. Bull. Str. Settlements*, **9**: 115 (1935);

FIG. 2 (i). *Chonemorpha fragrans* (Moon) Alston: (1) Shoot with flowers; (2) Flower; (3) Calyx; (4) Fruit; (5) Seed.

Chatterjee in *Kew Bulletin*, **1947**: 49 (1947); *C. mærophylla* Kurz in *Jour. As. Soc. Bengal*, **46**: 257 (1877). The specific epithet is evidently a typographical error for *C. macrophylla* as pointed out by Chatterjee (*l.c.* 50); *C. macrophylla* var. *grandis* A.DC., *Prodr.*, **8**: 450 (1844).; *C. mollis* Miq. in *Fl. Ind. Bat.*, **2**: 444 (1856); Kurz in *Jour. As. Soc. Beng.*, **46**: 257 (1877); Furtado in *Gard. Bull. Str. Settlements*, **9**: 116 (1935); *C. Rheedei* Ridley in *Agri. Bull. Str. and Fed. Mal. States*, **10**: 146 (1911).

In 1935, Furtado, in his key to the species of *Chonemorpha*, broadly classified the leaves into 2 sections, one elliptic to obovate, usually more narrowed in the lower half than in the upper and the other, ovate, oval elliptic-oblong or almost orbicular, usually more narrowed in the upper half than in the lower. On the basis of this very variable leaf character (as could be seen in Fig. 2 (i), Leaves *a*, *b* and *c*) and also on very minor difference in the calyx, he included *C. macrophylla* (Roxb.) G. Don in the first of the above sections and two species, *C. fragrans* (Moon) Alston and *C. mollis* Miq. in the second. From the sheets which he quoted under *C. macrophylla* (Roxb.) G. Don and *C. fragrans* (Moon) Alston, it is evident that he had not examined any South Indian collections of *C. macrophylla* (Roxb.) G. Don. except perhaps the Ceylon sheet, Thwaites C.P. 2467. From the South

FIG. 2 (ii). *Chonemorpha assamensis* Furtado: (1) Shoot with flowers; (2) Flower; (3) Calyx; (4) Fruit.

Indian collections, it is clear that both the types of leaves as noted by Furtado in his key, are present on the same shoot (*vide* Fig. 2, (i), (1) and hence the shape of leaf forms a very variable character. The minor variations of calyx mentioned by Furtado have also been observed in the same species. Therefore, the Ceylon species of Furtado, *C. fragrans* (Moon) Alston is only the same as *C. macrophylla* (Roxb.) G. Don. Similarly *C. mollis* Miq. is not a distinct species and is the same as *C. fragrans* (Moon) Alston (syn. *C. macrophylla*) as correctly indicated by Chatterjee (*l.c.* 52)

Chonemorpha fragrans (Moon) Alston is a huge climber 12–21 metres long with stem $1\frac{1}{4}$–5 cm. in diameter. Leaf glossy, deep green above and finely tomentose below. Flower is white and fragrant. Fruit is light green with a waxy gloss and usually each follicle is 25–38 cm. long and $1\frac{1}{2}$–$2\frac{1}{2}$ cm. in diameter. Due to its wide range of distribution, the species exhibits slight variations as regards the hairiness and size of the leaves.

Distribution

This is the most widely distributed species of the genus. It occurs throughout India, Ceylon, Andamans and Burma ranging from plains to high altitudes as far as 5,000 ft. It has also been collected from

FIG. 2 (iii) *Chonemorpha blancoi* Merr: (1) Shoot with flowers; (2) Flower; (3) Calyx.

different localities of Malayan Peninsula where it has not been reported beyond the altitude 500 ft. and also from Java.

Material examined

India—

Bengal: Calcutta Botanic Garden (*Lane*, 11270), (*Wallich Cat.*, 1657 B), (*Herb. Sulp. Kurz.*); Buxa Reserve, W. Duars (*Gamble*, 7698); Duars, N. Bengal (*Prain*, without number).

E. Himalaya: Slik, Sikkim (*Ribu*, 873, 2 sheets); Teendaria (*Gamble*, 3223 B, C, 3 sheets); Sikkim, Alt. 2,000–4,000 ft. (*J. D. Hooker*, Herb. Ind. Or. H.f. & T., 3 sheets); Munsong, Alt. 3,000 ft. (*Craib*, 437); Sittong, Sikkim (*Prain*, on 13th May 1903); Mungpoo, Alt. 3,000 ft. (*Cousins*, 25), (*Kari, Prain's coll.*, on 13th June 1902); Tunlioke, Sikkim (*Anderson*, 837, 307, without number); Sikkim (*Anderson*, without number).

Assam: Khasia Hills (*Gallatly*, 560), (*Griffith*, without number), (*Hooker*, Herb. Ind. Or. H.f. & T.); Umling, Alt. 850 ft., Khasi Hills (*Kanjilal*, 4018); Ghiri Ghat, Alt. 1,500 ft. (*Meebold*, 6298); Tengali Bam, near Naga Hills (*Prain's coll.*, in April 1898); Gauhatty (Specimen B, *Simons*, in June 1848, *pro parte*); Sylhet (*Wallich. Cat.*, 1657 A, Topo-type!).

N.-W. Himalaya: Dehra Dun (*Mackinnon*, in Aug. 1897); Below Mussuri, Alt. 4,000 ft. (*Mackinnon*, on 20th Aug. 1898); Kumaon, Alt. 3,500 ft.

FIG. 2 (iv) *Chonemorpha griffithii* Hook. f.: (1) Shoot with flowers; (2) Flower; (3) Calyx; (4) One follicle.

(*Strachey et Winterbottom*, 231, 2 sheets); Amparaw, Alt. 3,500 ft., Kumaon (*Gill*, 677); Kumaon (?) (*Falconer*); Kumaon (*Wallich Cat.*, 1658, 2 sheets).

Peninsular India: Collector's Bungalow, Chatrapur, Ganjam Dist. (*Fischer*, on 20th Aug. 1903); Bombay Prov. (Specimen A, *Gibson*, without number); Astoll, Alt. 2,000 ft., Belgaum Dist. (*Talbot*, 2121); Kumbharwada, Alt. 1,500 ft., N. Kanara (*Sedgewick and Bell*, 6051); Ruskee (?), N. Kanara (*Talbot*, 81); Peninsulæ Ind. Or. (*Wight*, 1880, *pro parte*); Malabar, Concan, etc. (*Stocks*, *Law*, etc.); Thorai, Travancore State (*Calder and Ramaswami*, 351, 2 sheets); Trivandrum (*Rama Rao*, 2330).

Ceylon—

Loc. incert. (*Thwaites*, C. P., 2467), (*Watson*, 179, Sepcimen B).

Burma—

Tacpo, Alt. 5,000 ft., Tennasserim (*Gallatly*, 775 ?); Khaywe, Shwegyin Dn., Tenasserim Circle (*Divl. officer*, 4, letter d. 6th Sept. 1903); Lashio, Alt., 2,600 ft., N. Shan States Dist. (*Lace*, 5838); Shan States Dist. (*Allen*, 2)

Andamans—

Loc. incert. (*Prain's coll.*, 57, 2 sheets); Wimkeoleygang (*Parkinson*, 619); Mangrove Bay, S. Andamans (*Kurz*, without number).

Malayan Peninsula—

Loc. incert. (*Scortechini*, 921, Herb. Mus. Perak); Goping, Alt. 300–500 ft. (*Kunstler*, 6000); Dispong, Perak (*Kunstler*, 7304, 2 sheets); Mt. Tupai, Perak (*Wray Jr.*, 2685, 3 sheets); Batu Togok, Alt. 200 ft. (*Wray Jr.*, 2183); Larut, upto Alt. 500 ft., Perak (*King's coll.*, 3636).

Java—

Java, Loc. incert. (*Horsfield*, purchased in 1859); Littoral forests, Djawana, Java (*Teysmann*, without number, Herb. Sulp. Kruz.).

FIG. 3(i). *Chonemorpha penangensis* Ridley: (1) Shoot with flowers; (2) Flower; (3) Calyx.

2. **Chonemorpha assamensis** Furtado in *Gard. Bull. Str. Settlements* 9: 115 (1935). I have seen the holotype [Fig. 2, (ii)]. The plant though resembling *C. fragrans* (Moon) Alston and *C. macrantha* Pitard in leaf and corolla characters, appears to be quite distinct in having a very short (4–5 mm. long), cup-shaped calyx with lobes divided upto nearly half its length and short peduncle. As the original description by Furtado appears very meagre, a detailed description of the species is given below.

Leaves: Opposite, petiolate, broadly obovate-oblong, 19–22 cm. long, 12–14 cm. broad, acute, entire, base cuniate, rounded, glabrous above, finely pubescent below, sub-coriaceous, pinnately reticulate, mid-rib channelled above, primary veins 10–12 pairs, slightly curved near the margin; *Petiole*: finely pubescent 2–3 cm. long; *Flowers*: on shortly peduncled terminal cymes; peduncle 4 cm. long, bracteate, pedicellate, hermaphrodite, actinomorphic, hypogynous; *Bracts*: many subtending the flowers, conical, 2–3 mm. long; *Pedicels*: 1·5–2 cm. long; *Calyx lobes*: 5, united, crateriform, glabrous, 4–5 mm. long, lobes nearly half the length of calyx; *Corolla lobes*: 5, united, hypocrateriform, 7 cm. long in bud including lobes, 1·5 cm. in diameter at the mouth, narrower near the middle, the basal bulged portion much above the mouth of calyx, corolla tube 3·5–4 cm. long, open corolla

* Fig. 3 (ii). *Chonemorpha valvata* Chatterjee: (1) Shoot with flowers; (2) Flower; (3) Calyx (*a* & *b*).

7–8 cm. in diameter, twisted, glabrous, thin, multinerved; *Style*: 7–9 mm., slender, glabrous; *Stigma*: flattened, round, saucer-shaped; *Fruit*: a pair of follicles, each follicle 18–20 cm. long and 1–1·5 cm. in diameter.

Distribution

There are now only two sheets collected from Assam, one with flowers and the other with fruit only. So it is too premature to say anything about its distribution, but it is quite likely that this species by further exploration may be collected from regions adjacent to Assam.

Material examined

India—

Assam: Chirapunji (written in Hindi) (collected by a native collector under the supervision of *G. Mann* in May 1893, Holotype!); Chima, Garo Hills (*King's coll.*, without number, in 1890, specimen with fruit).

3. **Chonemorpha blancoi** Merrill, Spec. Blancoanæ, 312 (1918) *et Enum. Philipp. Fl. Plants*, 3: 335 (1923); *Tabernæmontana elliptica* Blanco in *Fl. Filip.*, 115 (1837) (*non T. elliptica* Thunb., *Fl. Jap.*, 3: (1784); *Chonemorpha macrophylla* Vidal *non* G. Don, *Cat. Pl. Prov. Manila*, 36 (1880); *C. elliptica* (Blanco) Merrill et Rolfe in *Philip. Jour. Sci.* 3: 121 (1908); Chatterjee in *Kew Bull.* **1947**: 48 (1947).

Fernandez-villar sunk this species as a synonym under *C. macrophylla* (Roxb.) G. Don while Furtado (*l.c.*) reduced it to *C. mollis* Miq. as both the plants are somewhat similar in size and nature of calyx of *C. blancoi* Merr. This read along with the reductions of *C. macrophylla* and *C. mollis* under *C. fragrans* (Moon) Alston, would naturally take the distribution of *C. fragrans* (Moon) Alston as far as the Philippines. But this is very doubtful as *C. fragrans* (Moon) Alston does not appear to have extended to the Philippines. *C. blancoi* Merr. is a distinct species characterised by very long petioles and ovate-elliptic leaves with distinct cordate leaf base. Though the calyx is closely allied to that of *C. fragrans* (Moon) Alston, the corolla is distinctly smaller than that of *C. fragrans* (Moon) Alston, its tube measuring 2–2·5 cm. long.

Distribution

This species appears to have been confined to a very limited area like the Philippine and Celebes islands. In Philippines, it is widely distributed at low and medium altitudes of the primeval forests of Luzon. It has also been collected from N.W. Celebes. According to Merrill, this is an endemic species of these islands.

Material examined

Philippines—

Tatay, Palawan (*Merrill*, 9249); Mount Belulao, Batangas Prov., Luzon (*Merrill*, Sp. Blancoanæ, 482); Bosoboso, Morongo, Luzon Central (*Loher*, 3881); Horto Botanico Bogor (*Herb. Sulp. Kurz.*, 1452).

Celebes—

Bonto Parang, N.-W. Celebes (*Bünnemeijer*, 10572).

4. **Chonemorpha griffithii** Hook. f., *Fl. Br. Ind.*, **3**: 662 (1882). This is a distinct species of the genus as pointed out by Chatterjee (*l.c.*). The leaf is smaller than that of *C. fragrans* and *C. assamensis*, not exceeding 19 cm. in length and 10 cm. in breadth. Though the Corolla is similar to that of the above two Indian species, the distinct feature of this plant is the calyx which is deeply 5-partite with imbricate lobes [as shown in Fig. 2,(iv)]. There is no calyx-tube. Fruit is a pair of follicles, each follicle being 22–28 cm. long and 1½–2 cm. in diameter.

Distribution

This appears to have a restricted distribution mostly confined to the E ern Himalayas and hills of Assam reaching upto the altitude of 5,000–6,000 ft.

Material examined

India—

E. Himalaya: Tony, Alt. 5,000 ft., Sikkim (*Younghusband*, on 29th June 1903); Kurseong, Alt. 4,500 ft., Sikkim (*Kurz*, without number), (*Anderson*, 265); Rishap, Alt. 2,500–3,000 ft., Darjeeling Dist. (*Clarke*, 11782 D, H), (*King*, 4338); Sikkim, Alt. 2,000–4,000 ft. (*Thomson*, in 1857), (*Hooker*, Herb. Ind. Or.), (*King*, 768, 5 sheets), (*Anderson*, 302), (*Kurz*, without number; Rungpoo, Alt. 5,000 ft. (*Gamble*, 793 D); Puttabong, Alt. 5,500 ft., Darjeeling Dist. (*Gamble*, 8209); Newtincel (?), Alt. 5,000 ft., Sikkim (*King*, on 29th May 1879, 3 sheets); Parmeeaklong, Sikkim (*Anderson*, 837); Mungpoo, Alt. 6,000 ft. (*Kari*, 1357).

Assam: Khasia Hills (Specimen A, *Simons*, in July 1850, *pro parte*).

5. **Chonemorpha penangensis** Ridley in *Agric. Bull. Str. and Fed. Mal. States*, **10**: 147 (1911); *Fl. Malay Pen.*, **2**: 360 (1923); Furtado in *Gard. Bull. Str. Settlement*, **9**: 116 (1935); Chatterjee in *Kew Bull.*, **1947**: 51 (1947).

This species is a climber of 6–12 metres long, with stems about 2½ cm. in diameter. Flower buds are tinged pink but open flowers are white with yellowish tinge inside the throat. This species resembles *C. fragrans* (Moon) Alston particularly in the leaf character. But in floral characters, it is distinct from other species by the nature of long, hairy or finely pubescent calyx, slightly constricted at the apex with 5 very short pointed teeth-like lobes [as shown in Fig. 3, (i), (3)] and by the presence of comparatively smaller corolla lobes. As regards *C. mollissima* Boerlage which has been suspected to be similar to *C. penangensis*, I have not seen the type. Boerlage in *Flor. Van Ned. Ind.* 2 (1899) has noted—"In Rijks Herbarium there is a kind of *Chonemorpha mollissima* which has not been described. Its origin is not very clear. It differs from *Chonemorpha macrophylla* Don in:—(1) that the glossy calyx has very short teeth (2) that the corolla tube does not pierce outside the calyx when the flower opens (3) and that it has glossy leaves." On this basis, none of the characters except the short teeth of the calyx matches with those of *C. penangensis*. The character that corolla tube does not pierce outside the calyx is rather unusual in this genus and hence I doubt very much whether this species belongs to the genus, *Chonemorpha*

at all. However the matter can be decided only by examining the type of *C. mollissima* Boerlage" (Translated from Dutch through the kindness of Rev. H. Schepers, S. J., of St. Xavier's College, Calcutta).

Distribution

This species has a restricted distribution, being confined mostly to the Malayan Peninsula. It usually occurs at different altitudes between 300–800 ft. in the mixed jungles of Penang and Perak.

Material examined

Malayan Peninsula—

Malacca (*Maingay*, 1837 = Kew No. 1074); Brisu, Malacca (*Derry*, 543); Upper Perak, Alt. 300 ft. (*Wray Jr.*, 3661); Perak, Alt. 300–800 ft. (*Bubong*, King's coll., 10574); Balek Palau, Penang (*Ridley*, 3441).

6. **Chonemorpha valvata** Chatterjee in *Kew Bull.*, **1947**: 51 (1947). This is a good species. The distinct features of this species are the shrubby nature of the plant and the deeply 5-partite (almost free) calyx with valvate lobes. A detailed description has been given by Chatterjee (*l. c.*).

Distribution

The species has so far been reported from the hilly tracts of Upper Burma (Southern and Northern Shan States), S.W. China (Yunnan) and Siam at the altitude of about 4000–5500 ft. As this is a recently described species it is rather too early to discuss about its region of distribution.

Material examined

Burma—

South Shan States, Loc.? (*MacGregor*, 578); Upper Burma, Mogok, 4,000 ft. Alt. (13th June 1914, *Rodger*, 120, Iso-type!).

7. **Chonemorpha pedicellata** Seshagiri Rao sp. nov. *Chonemorpha grandiereana* Pierre ex Spire arcte affinis sed pedicellis et pedunculis longioribus, corolla brevioribus foliis majoribus differt.

Leaves: petiolate, elliptic, 22–27 cm. long, 11·5–14·5 cm. broad, acute, entire, base narrow, glabrous above, finely pubescent below, midrib channelled and hairy above, primary veins 10–11 pairs, gently forming loops near the margin, petioles finely pubescent, 2–2·5 cm. long; *Inflorescence*: on long peduncle, finely pubescent when young, 14–20 cm. long, cymose, many flowered, bracts softly tomentose, lanceolate, 9–11 mm. long; *Flowers*: on very long pedicels which are finely pubescent and 3·8–5 cm. long; *Sepals*: 5, united, finely pubescent, 12–15 mm. long, 4–5 mm. broad, lobes: narrow, conical, about $\frac{1}{3}$ the length of calyx; *Petals*: 5, united, hypocrateriform, corolla tube more or less cylindrical, abruptly tapering downwards near the base, 4·5–5 cm. long, lobes twisted to left, obliquely obovate, finely multinerved, about 3·5 cm. long and 1·5 cm. broad.

FIG. 4. Type of *Chonemorpha pedicellata* Seshagiri Rao sp. nov. (Nearly $\times\frac{1}{2}$)

R. Seshagiri Rao

This species resembles *C. grandiereana* Pierre ex Spire in having almost similar calyx but differs in having long pedicels and peduncle, shorter corolla and larger leaves.

Distribution

No definite area of its distribution can be stated as there is only one species from N.W. India, that too without any precise locality.

Material examined

India—

Loc. (?) N.-W. India (*Hb. Royle*; *Typus*!).

(This sheet was named as *Chonemorpha macrophylla* Don and was mixed along with the bundles of that species in the Calcutta Herbarium.)

Summary

1. *Chonemorpha fragrans* (Moon) Alston which was considered as the Ceylon species by Furtado, is nothing but the most common species once known as *C. macrophylla* (Roxb.) G. Don.

2. *Chonemorpha assamensis* Furtado has been described in detail.

3. According to the Homonym rule, *Chonemorpha blancoi* Merr. is the valid name and not *Chonemorpha elliptica* (Blanco) Merrill et Rolfe.

4. Additional notes on *C. griffithii* Hk. f. and *C. penangensis* Ridley have been given.

5. A new species *C. pedicellata* Seshagiri Rao sp. nov. has been described.

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EFFECT OF CERTAIN AMINO ACIDS AND GROWTH REGULATING SUBSTANCES ON THE SURVIVAL AND ROOTING BEHAVIOUR OF *DURANTA PLUMIERI* CUTTINGS

By R. S. Choudhri and B. K. Gaur

College of Agriculture, Banaras Hindu University

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Introductory

Duranta plumieri is a common hedge plant and is popularly planted around most ornamental gardens and on road sides. If properly and frequently trimmed, it forms a unique hedge for gardens and in view of possessing a fairly prickly character, it also serves as ample protection from cattle and trespassers. It can nicely be cut into beautiful and picturesque designs and almost supersedes every other hedge in this respect.

Duranta though fairly hardy, has a high water requirement at least in the early stages of growth. For this reason, its plantation by cuttings has only been possible during rains. Experience has shown that this plant can better survive as a hedge, if previous to permanent planting, its cuttings are allowed to root in a nursery bed where facilities for watering could be adequate. Because of the extreme popularity of *Duranta* as a hedge plant, it was considered desirable to study the effect of certain amino acids and growth regulating substances on the rooting behaviour of its cuttings.

Material and Method

Duranta cuttings about 25 cm. in length and 2·50 mm. in girth bearing on an average 30 leaves were obtained from the hedge of the college garden. Special care was taken to have these cuttings of almost the same age. This step was considered essential with a view to nullifying the age factor on the rooting of cuttings which might otherwise markedly affect their capacity to root. Zimmerman and Hitchcock (1946) working on *Syringa vulgaris* L., *Pyrus malus, Kalanchæ daigremontiana, Spiræa bumalda* and *S. vanhouttei* cuttings found that the change in structure of protoplasm of plants with age is a major controlling factor on the mechanism in plants through which chemicals act and roots are formed. The basal ends of these cuttings were given uniformly oblique cuts so as to expose a larger stelar surface for treatments. The following compounds in concentrations ranging between 10 and 1,000 p.p.m. were used for the treatment of cuttings:

Glutamic acid,
Amino-succinic acid,
Indoleacetic acid,
Indolepropionic acid,
Phenoxyacetic acid, and
2, 4-dichlorophenoxyacetic acid.

Solutions of all compounds were made in distilled water, but a little alcohol was used in certain cases where the compounds did not fully dissolve in water.

The experiments were started on September 18, 1951 and the basal ends (about 5 cm.) of cuttings were immersed in the respective solutions, kept in 250 ml. beakers for 15 hours from 5–30 P.M. to 8–30 A.M. The planting of all experimental cuttings was done in special nursery beds, immediately after the soaking period was over. Every treatment was replicated 4 times to make any fortuitous observations unlikely; each replication consisted of a dozen cuttings.

A set of untreated cuttings was planted side by side for the purpose of comparison. A second control was also maintained by presoaking the cuttings in tap water, in the same manner and for the same period as used for other treatments. This was done primarily to have its comparison with the unsoaked control and secondly to precisely identify the after-effects, following other treatments where also water was used as a solvent and a carrier.

With a view to studying the practical possibility of this scheme, these experiments were preferentially conducted off-season in September and the following months, when the rains in this part of the country had completely stopped. No special manures or fertilizers were added to the nursery bed, but weeding and hoeing were carried out at successive intervals.

Following plantation a light watering was given to the bed and this was repeated every alternate day for the first two weeks. Watering for the next 3 weeks was carried on at weekly intervals and during the month of November only fortnightly. All plantlets were later on left practically uncared for to be subjected to the forces of weathering, the effect of which was studied on survival percentage and rooting behaviour of these cuttings.

Observations

The plantation of *Duranta* cuttings of all the experimental series was done on 19th September 1951, and the experiments continued until November 11, 1951. The weather conditions prevailing in this region during the period of experimentation of nearly 8 weeks have been presented in Table I.

TABLE I

*Certain meteorological observations recorded at the Banaras Hindu University**

Month	Max. Temp. °F.	Min. Temp. °F.	Humidity %	Rainfall (inch.)
	(Average 1938–50)			
July ..	92·7	79·3	86·0	11·87
August ..	90·7	78·1	84·4	14·67
September ..	91·9	77·5	84·7	9·90
	1951			
September (17th to 30th) ..	95·9	76·8	81·0	0·32
October ..	95·6	74·4	81·3	0·02
November ..	92·1	60·7	66·6	0·00

* Banaras is situated in latitutde 25° 19′ and longitude 83′ 03′ at a height of 267 feet above mean sea level.

In order to have a more sound correlation of the above with the findings of this investigation, averages of the past 13 years of meteorological observations (*cf.* Maitra, 1950) have also been tabulated along side.

An analysis of the data presented above would reveal several points of interest, such as the maximum temperature during the months of July and August averaged 91° F., the minimum being 78·5° F. Contrariwise, during the months of Setpember, October and November, the maximum and minimum temperatures were 95° and 91° F. respectively. This indicates that the average maximum temperature is usually high and average minimum temperature low during the months following rains. Similarly, there is quite a marked difference in the percentage humidity, 85 being during the months of July and August and only 77 during the next 3 months that follow. The average rainfall is over 13″ during the months of July and August as against almost nil in the subsequent months of September to November. These factors of environment are likely to affect the initiation of roots in *Duranta* cuttings as also the growth and development of plantlets.

It may be noted that despite regular irrigation, all the untreated cuttings, which were not soaked even in water prior to planting, died within 10 days. A second plantation was, therefore, taken recourse to on 29th September 1951. Even in this case, the survival percentage was too low, being only 4·5. Roots formed on such cuttings were smaller in size and fewer in number. No new leaves were

formed on these cuttings even after a lapse of 2 months. The high mortality of these untreated controls was obviously due to the inclemency of weather, perhaps, high temperature and low humidity.

TABLE II

After-effects pertaining to survival percentage and rooting in cuttings of Duranta plumieri *following treatment with certain amino acids and growth regulating substances*

Treatment	Concentration (p.p.m.)	Average survival (%)	Average roots (No.)	Average root length (cm.)
1. Unsoaked (Control) ..	..	4·5	9·0	10·0
2. Water soaked (Control) ..	..	53·8	16·6	10·7
3. Glutamic acid ..	10	75·0	20·2	12·3
	100	58·3	13·4	11·0
	1000	33·3	10·3	9·2
4. Amino-succinic acid ..	10	58·3	15·8	9·4
	100	50·0	15·2	7·9
	1000	25·0	14·5	12·7
5. Indoleacetic acid ..	10	66·7	44·0	8·8
	100	66·7	23·2	8·8
	1000	50·0	18·8	9·8
6. Indolepropionic acid ..	10	83·3	11·6	19·6
	100	75·0	15·0	12·0
	1000	0·0	0·0	0·0
7. Phenoxyacetic acid ..	10	53·8	13·6	10·3
	100	41·7	15·4	8·8
	1000	16·7	5·0	3·2
8. 2, 4–Dichlorophenoxy-acetic acid ..	10	8·3	13·0	3·7
	100	0·0	0·0	0·0
	1000	0·0	0·0	0·0

Cuttings soaked overnight in water before plantation, on the contrary, exhibited a fairly good stand and quick rooting with the result that the percentage of survival in this case averaged 54 (Table II). Roots formed on these cuttings were more in number. The older leaves dried away with age without any yellowing. Distal ends of leaves began withering first. Fresh leaves formed remained green throughout. A fair resistance of plants to stand the adverse weather conditions may here be accounted to early initiation of roots in the cuttings which continued to maintain a good stand with subsequent watering facilities.

Amongst the amino acids tried in this work, glutamic acid fared better than amino-succinic acid (Table II). It was interesting to note that the survival percentage as well as the root growth of cuttings were inversely proportional to the concentrations employed in this treatment. The compound was highly effective in a concentration of 10 p.p.m. It was characterized with 75 per cent. survival. Cuttings following this treatment rooted profusely. The foliage developed

was best in this case and the leaves formed were largest of all the experimental sets. Some of the plantlets belonging to this series even began to bear flowers within 6 weeks of plantation.

Cuttings treated with relatively low concentrations of aminosuccinic acid responded like the water-soaked series. Withering of older leaves here, however, started earlier, from base to top, obviously due to the direct action of the acid on the place of application and in its vicinity. No yellowing of leaves occurred in this case.

Analysing the effects of growth-regulating substances, it was noted that indoleacetic acid initiated a fairly good stand in plants. The survival percentage following this treatment approximated 67 and cuttings excelled in their capacity to root (Table II). At a concentration of 10 p.p.m. the roots formed on cuttings were over 2½ times more than those formed in the water-soaked-controls. Increase in root length was, however, not proportionate. Foliage growth was vigorous. Treatments with indolepropionic acid were also highly effective. Survival percentage following this treatment in 10 p.p.m. concentration was highest (83·3 per cent.) and roots formed were longest of all the series (about 20 cm.). Even at a concentration of 100 p.p.m. the survival percentage was 75. No sprouting was, however, possible at a still higher concentration of 1,000 p.p.m.

Substituted phenoxy compounds did not cause any stimulating effect, either on the survival percentage, or on the rooting response of *Duranta* cuttings. The effects of phenoxyacetic acid in a low concentration of 10 p.p.m. were very much the same as resulting from the water-soaked series. The survival percentage, however, decreased as the concentration of the solution increased. The treatment of cuttings with 2, 4-dichlorophenoxyacetic acid, even in a low concentration of 10 p.p.m., was not found to be useful. Survival percentage was very low and root initiation greatly inhibited. Like the untreated controls, here also, majority of plants died, withering effect evincing earlier or later depending upon the concentration of the compound. A few plants, which survived the treatment of 2, 4-D had an erect posture for a week, but leaf chlorosis developed earlier. Leaf drop, however, started 12 days after planting.

A general survey of the observations made will bring to light the fact that in lower concentrations of 10 p.p.m.. some of the compounds, used here, stimulated rooting and enhanced the survival percentage. A few compounds, however, did not prove effective and still others proved injurious. The fact, however, remains that injurious effects followed the treatment of cuttings with increase in concentration of one or the other of these compounds.

If root formation and survival percentage both are taken into consideration and particularly the latter, because it forms the major concern in plant propagation, glutamic acid and indolepropionic acid may be considered as highly effective in initiating beneficial responses in *Duranta* cuttings. It might be mentioned that a pre-treatment with

one or the other of these compounds was so effective that even when plants were left uncared for and even unwatered for several weeks at a stretch, they stood firm and healthy. A pre-treatment of cuttings with solutions of one of these compounds may, therefore, be undertaken with advantage. As the experiments were carried on, after the rains had ceased and the weather was adverse to usual plantations of *Duranta* by cuttings, such pre-treatments should prove highly useful in off-season projects of this nature. This makes possible the practical application of these treatments.

Discussion

The precise manner of the action of the amino acids and the growth-regulating substances in the tissue responses is not clear. The available experimental data seem most satisfactorily interpreted by assuming that the basic rôle of the applied substances used in this work is to bring about a mobilization of materials towards the site of the treatment. While discussing the growth-promoting action of molasses, Classen (1942) postulated that the effect was due to certain amino acids functioning as essential nutrients in the formation of new cells. Considering the mechanism of action of growth-regulating substances, Went (1934) has shown that it is possible to separate two phases in the action of indoleacetic acid towards the formation of roots on cuttings. The first phase is tentatively identified with a redistribution of the hormone rhizocaline within the stem. This phase can be induced by a number of substances not active in root formation proper. The second phase can be induced by indoleacetic acid and similar phytohormones; this phase may be an activation of the accumulated rhizocaline. There is also ample evidence that the rate of starch hydrolysis is increased in treated regions (*cf.* Stuart and Marth, 1937; Stuart, 1938; Mitchell and Whitehead, 1940 and Choudhri, 1948). This would make carbohydrates more readily available for growth processes.

The toxic action of growth substances has been attributed by Macht and Grumbein (1937) to the use of concentrated solutions on the one hand and the longer period to which the plants had been exposed on the other. Similarly Grace (1937) made an attempt to solve the paradox of growth inhibition by synthetic growth substances. He also attributed the phenomenon to over-dosage. As a consequence, perhaps, the mobilization of rhizocaline is inhibited and which in turn affects the growth response of cuttings. Adverse effects in the treated series in the present work may be explained accordingly.

The coefficient of correlation between the survival percentage and the number of roots after computation has been found to be 0·67 and in between the survival percentage and the length of roots 0·69. The insignificant deviation of the value of '*r*' in the two cases well indicates that both the elongation in roots and their number are essential contributors to the well being of the plant and both of them play so important a part towards the growth and upkeep of the plant that none of the two could be ignored.

Summary

The present investigation was undertaken with a view to determining the effect of certain amino acids and growth-regulating substances on the survival and rooting in cuttings of *Duranta plumieri*. Glutamic, amino-succinic, indoleacetic, indolepropionic, phenoxyacetic, 2, 4-dichlorophenoxyacetic acids were used in concentrations ranging between 10 and 1,000 p.p.m. and administered as pre-planting treatments to the cuttings. Both unsoaked and water-soaked controls were maintained for purposes of comparison. The cuttings used were approximately of the same age, of the same dimensions and each set consisting of a dozen cuttings was replicated 4 times.

In order to throw light on the practical bearing of this scheme of treatment, the plantation was done in the third week of September 1951 (off-season) when the rains had stopped and the weather prevailing precluded the possibility of growth and establishment of such cuttings. Weather records were, therefore, maintained to correlate the after-effects of the treatments. Watering and hoeing were carried on uniformly in all the sets, in the beginning at more frequent intervals but later on only occasionally. The following conclusions have been the outcome of the above enquiry:

Unsoaked controls could not stand adverse weather conditions and most cuttings dried and died in a short period of time. Soaking in water, previous to planting, initiated quicker rooting and brought about a higher survival percentage.

When employed in lower concentrations, indolepropionic acid initiated the formation of longest roots and highest survival percentage.

Indoleacetic acid, though it induced the formation of largest number of roots, was relatively less efficacious towards the survival of plantlets. Treatment with glutamic acid was characterized with the formation of prolific foliage and initiated high survival percentage.

Amino-succinic and phenoxyacetic acids did not prove to be very effective, while 2, 4-D treatments were generally deleterious.

As survival percentage is the major concern in raising plants from cuttings, pre-treatment with dilute solutions of either indolepropionic or glutamic acid will be highly useful.

References

Choudhri, R. S. 1948. Studies of the effects of certain plant hormones on growth, general behaviour and food transport of *Phaseolus vulgaris* L. Cornell Univ., U.S.A., Ph.D. Thesis.

Classen, H. 1942. Die Wuchsstoffe der Hefe und ihre Bestimmung in den Nahrlösungen, besonders in den Melassen nach der. Methode von Nielsen. Zeitschr. Spiritusindust. 65 (1/2).

Grace, N. H. 1937. Physiological curve of response to phytohormones by seeds, growing plants, cuttings and lower plant forms. Canadian J. Res. 15: 538–46.

MACHT, D. I. AND GRUMBEIN, M. L. 1937. Influence of indoleacetic, indolebutyric and naphthaleneacetic acids on roots of *Lupinus albus* seedlings. Amer. J. Bot. 24: 457–60.

MAITRA, S. K. 1950. Abstract of meteorological observations (Jan. 1934–Dec. 1949), Banaras Hindu University, Banaras.

MITCHELL, J. W. AND WHITEHEAD, M. R. 1940. Starch hydrolysis in bean leaves as affected by application of growth-regulating substances. Bot. Gaz. 102: 393–99.

STUART, N. W. 1938. Nitrogen and carbohydrate metabolism of kidney bean cuttings as affected by treatment with indoleacetic acid. Bot. Gaz. 100: 298–311.

——— AND MARTH, P. C. 1937. Composition and rooting of American holly cuttings as affected by treatment with indolebutyric acid. Proc. Amer. Soc. Hort. Sci. 35: 839–44.

WENT, F. W. 1934. On the Pea-test method for auxins, the plant growth hormone. Proc. Kon. Akad. van Wetensch Amsterdem, 37: 547–55.

ZIMMERMAN, P. W. AND HITCHCOCK, A. E. 1946. The relation between the age of stem tissue and the capacity to form roots. J. Gerontology. 1 (i).

ANTHRACNOSE DISEASE OF *CARISSA CARANDAS* LINN. CAUSED BY *COLLETOTRICHUM INAMDARII*

By Akshaibar Lal and Ram Pal Singh

Plant Pathology Laboratory, College of Agriculture, Benaras Hindu University

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Introduction

Carissa carandas L., popularly known as 'Karaunda', is cultivated in various South-East Asian countries for its fruits and fencing.

So far *Pestalotia versicolor* is the only fungal parasite reported on this plant (Mundkur, 1942). The present paper describes an anthracnose disease caused by a species of *Colletotrichum*. The disease seems to be very widely distributed in various parts of Uttar Pradesh. At Banaras all the hedges of 'Karaunda' are seriously infected by it.

Material and Methods

Material for the study was obtained from various places in Uttar Pradesh. The organism was isolated from the affected tissue and purified by single spore culture. Hand sections were stained in cotton blue in lactophenol. For microtome sections the materials were fixed in Karpenchenko's solution and the sections were stained in Light Green and Magdala Red.

Symptoms

Pinkish red spots of the size of pinheads mainly confined to the leaves are the first indications of the disease. These spots increase in size and may spread over the greater part of the leaves. Lesions are irregular, later turn brown and are surrounded by a red margin which passes into the green colour of the leaf through a yellow halo. Sooner or later the central region turns grey in which minute scattered black dots representing the fructifications of the fungus are developed. In very severe cases the affected leaves dry up. In combination with *Pestalotia versicolor* this disease produces conspicuous dieback symtoms)Fig. 1).

Pathogenicity

Experiments were carried out on seedlings or on tender twigs kept in water. Inoculations were made in moist glass chambers on both surfaces of the leaf with or without injury using spore suspension or mycelial growth.

FIG. 1.—A & B. Different stages in the development of the disease.
C. The last stage showing 'die-back'.

It is obvious from Table I that infection occurs only after injury showing that the parasite is purely a wound parasite. The severity of the disease can be explained by the fact that bushes being thorny, the leaves are injured in windy weather. Spore suspension or mycelial inoculum are found to be equally effective on both the surfaces of the leaves irrespective of the presence or absence of stomata. Inoculum in leaf extract is able to infect uninjured leaves as well.

As infection occurs generally after injury the exudations of the plant seem to provide stimulation to the spores which become able to infect even the uninjured portions of the leaves in nature.

Cross inoculation experiments have indicated that neither the anthracnose of *Carissa carandas* is able to infect *Citrus medica* and cucumber nor the anthracnose of the above 2 plants is able to infect *Carissa carandas*. The fungus on *Carissa carandas* is therefore a different one and has been named *Colletotrichum inamdarii* after Prof. R. S. Inamdar, the teacher of the senior author.

TABLE I

Infection Experiments

Treatment of leaves			No. of leaves inoculated	No. of leaves infected	Percentage of infection
1 Spore suspension in water :					
(i) Uninjured	Upper surface	..	25	..	..
	Lower surface	..	20	..	..
(ii) Injured	Upper surface	..	26	26	100
	Lower surface	..	26	26	100
2 Mycelial growth :					
(i) Uninjured	Upper surface	..	23	..	..
	Lower surface	..	19	..	..
(ii) Injured	Upper surface	..	21	21	100
	Lower surface	..	21	21	100
3 Spore suspension in leaf extract :					
(i) Uninjured	Upper surface	..	19	18	95
	Lower surface	..	20	19	95
(ii) Injured	Upper surface	..	25	25	100
	Lower surface	..	15	15	100

MORPHOLOGY

The mycelium is localised in the diseased spots. It is thick, septate. branched and intracellular. When young the hyphæ are hyaline with granular protoplasm and no oil globules but when old they become thick-walled, brownish, septate, profusely branched with irregular swellings filled with granular substance containing oil globules. Thickness of hyphæ in the host cell varies from 1·4μ to 4·15 μ and in culture from 2 μ to 4·85 μ.

Acervuli occur on both the surfaces of the leaf and are visible to the naked eye as black dots.

In the formation of acervulus the mycelium collects to form a well-defined stroma of thick-walled cells tightly pressed together. The sides of the stroma are slightly raised to form a shallow grooved acervulus. The young acervulus is covered by the host tissue being slightly raised above the general surface. By the continued growth of conidia

and conidiophores the overlying tissue is ruptured and the acervulus is left open. Acervuli are bordered by black septate setæ (Fig. 2).

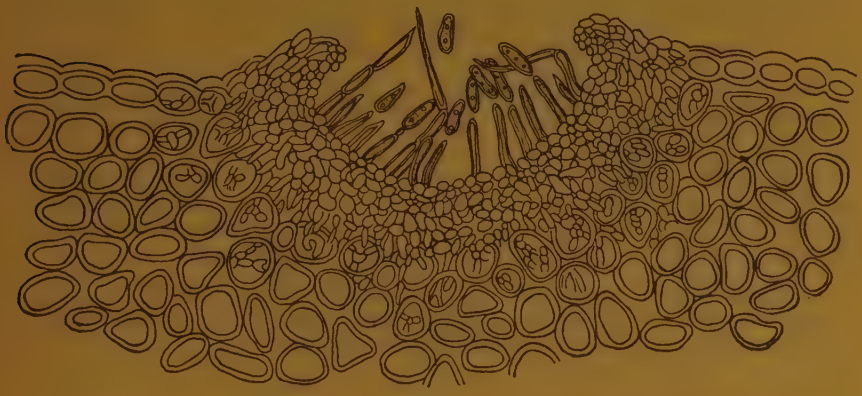


FIG. 2. Acervulus in section, showing setæ, conidia and conidiophore. Mycelium is intracellular.

Conidiophores are cylindrical, septate, unbranched projections arising from the surface of the stroma and filled with granular protoplasm.

Conidia are unicellular but become two celled before germination, oblong broadly rounded at the apices. They are hyaline individually but pinkish in mass embedded in gelatinous substance. The conidia contain two to several oil globules.

Setæ have been noted in culture as well as in nature. They are sterile hyphæ arising from the margin of the acervuli, thick-walled, septate, darker and longer than the conidiophores and pointed at the ends.

TABLE II

Size of various reproductive structures (μ) *on the host and culture medium*

Structure	Host	Culture media
1 Acervulus ..	69·25 to 204·45	176·19 to 545·20
2 Conidiophore ..	5·54 to 11·08	22·16 to 36·55
3 Conidia ..	11·12 to 26·41 by 2·98 to 5·56	
4 Setæ ..	30·47	55·4 to 77·56

DESCRIPTION OF THE SPECIES

Colletotrichum inamdarii sp. nov. spots confined to leaves, minute, deep pink with yellow halo, enlarging into irregular lesions. Lesions

have grey central region, bounded by shades of deep brown and pink with prominent yellow halo. Acervuli black, scattered in the grey central region, on both the surfaces, erumpent, setose and measure 69 μ to 204 μ average 110 μ in diameter. Conidiophores non-septate, hyaline, cylindrical, slightly tapering towards the distal end measuring 2·4 μ by 5·5–11·0 μ. Conidia, hyaline bacilliform, straight, stout, thin-walled, non-septate with two or more refractile globules measuring 11·0 to 26·0 μ by 2·98 μ to 5·56 μ.

Conidia become bicelled before germination. Setæ distributed irregularly, tapering towards the distal end, septate, black, brown measure 30·5 μ average. Stroma subepidermal, mycelium intercellular hyaline to light brown, measures 1·4 to 4·2 μ thick.

Habit.—On the leaves of *Carissa carandas*, L Banaras. Coll. Akshaibar Lal (August, 1945) type. The type specimen is deposited in the Herb. Crypt. Ind. Orient., New Delhi.

Latin Translation: *Colletotrichum inamdarii* Lal, spec. nov.

Maculæ in foliis tantum, minutæ, profunde roseæ, nimbo luteolo, mutantes in læsiones irregulares. Læsiones griseæ in regione centrali, circumdatæ tinctione alte brunnea et rosea, nimbo prominenti luteo. Acervuli nigri, dispersi in regione grisea centrali, in utraque pagina foliorum, erumpentes, setosi, magnitudinis 70 to 20 μ (110 μ) in diam. Conidiophori haud septati, hyalini, cylindrici, tenuiter fastigiati in apice semoto, magnit. 5·54 μ ad 11·0 μ longitudine. Conidia hyalina, bacilliformia, recta, valida, parietibus tenuis prædita, haud septata, duobus vel pluribus globulis ornata, magnit. 11 to 26 $\mu \times$ 2·9 to 5·56 μ. Conidia evadunt bicellulata ante germinationem. Setæ irregulariter dispersæ, fastigiatæ in apicem remotum, septatæ, nigrobrunneæ, magnit. 30·5 μ longitudine in medietate. Mycelium intracellulare hyalinum ad tenuiter brunneum, magnit. 1·4 to 4·2 μ crassitudine.

Typus lectus in foliis *Carissæ carandas* Linn., in loco Banaras ab Akshaiberlal, *mense augusto* 1955.

Hibernation

Spores are short lived and die within 1½ months' time. The organism has been found to hibernate through the mycelium in the tissue and become active in the next favourable season after the first rain and start the disease.

Germination of Conidia

Studies in hanging drop culture show that conidia germinate in sterile distilled water in 6–12 hours. Germ tube is formed at one end or at both the ends or even from the middle. Ordinarily one of the oil globules migrates to each of the daughter cells formed by septation. In the germ tube the oil globule breaks up into smaller ones and gradually disappears. The germ tube when it touches a hard surface swells up and a partition separates this swollen region where the oil globules reappear. The wall thickens, turns brown and the smaller oil globules

fuse together to form one prominent globule. The free end of the germ tube which does not touch the glass furface instead of producing appressoria, produces typical conidia. On hard surface like glass, there is no further development of the appressoria in distilled water, but in host extract suspension 80% of appressoria develop normal infection hypha after about 2½ hours at 22° C. During germination the single refractive body of approssorium breaks up into smaller ones. The wall of the appressorium ruptures and a fine germ tube develops at any point of the appressorium which elongates into infection hypha (Fig. 3).

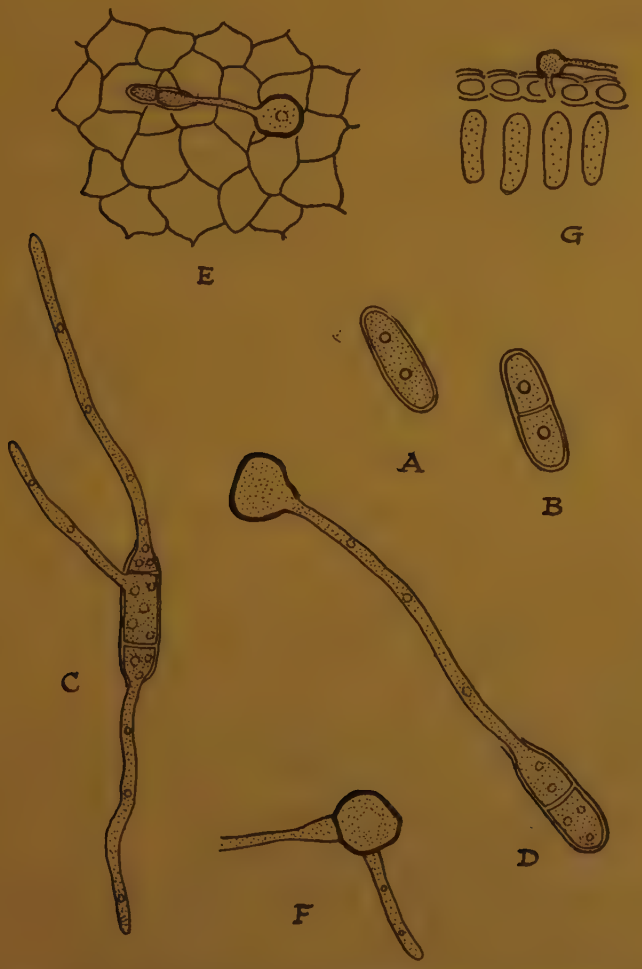


FIG. 3.—A. Conidium. B. Conidium before germination. C. Germtube formation. D & E. Formation of appressorium. F & G. Formation of infection hypha.

Spore suspensions in leaf juice and distilled water were also sprayed over the leaves which were incubated under bell jar in moist condition. On the host conidia germinate to form appressoria in both the cases but it is only in the case of spore suspension in leaf juice that appressoria develop infection hyphæ which penetrate the leaf. Dey (1919, 1933) also noted in the case of *Colletotrichum lindemuthianum* and *C. gleosporioides*, that the conidia germinate to form appressoria but the infection hyphæ do not develop unless there is a stimulation by the secretion of the host.

5·5% sucrose solution has been found to be the best for germination as it gives 87·8% germination after 11 hours as against 22% in sterile distilled water and 71·5% in host leaf extract. The germ tube length is also greatest (60·1 μ) in sucrose solution as against 45·5 μ in host leaf extract and 16·6 μ in sterile distilled water.

Temperature relation was studied by keeping hanging drop cultures at various temperatures ranging from 20° C. to 37° C. With increasing temperature the percentage of germination as also the length of the germ tube increase and reach their optimum (43·5%; 25 μ) at 30° C. after which there is a decrease. The conidia resist a temperature of 48° C. for 10 minutes but are unable to survive a temperature of 49° C. for the same duration.

pH of the medium affects both germination percentage and the length of the tube. The pH range suitable for germination varies widely (pH 4–10), the optimum being pH 7. Below and above this both the percentage of germination and the length of germ tubes decrease. At pH 3 and 11, germination stops altogether. Relatively, alkaline reactions (pH 8–11) seem to be more suitable than acidic reactions.

Growth and Nutrition

The growth of the fungus was studied on various solid and liquid media. All the media used were found suitable for the growth of the fungus. The fungus showed greater liking for such media as Richards' solution, potato dextrose and turnip juice both in solid and liquid form as compared to the host extract and Brown's starch.

Growth in various media seems to be mainly governed by the amount of sugar in the medium. Dry weight is greatest (2·432 gm.) in Richard's solution as it contains 5% sugar whereas it is least (0·98 gm.) in Brown's solution which contains only 0·2% sugar.

Relative growth rate has been calculated acording to the formula

$$R = 100 (\text{Log}_e W_2 - \text{Log}_e W_1)$$

where R represents the rate of growth in percentage and W_1 the initial growth in term of dry weight of the mycelium and W_2 the final weight of the mycelium.

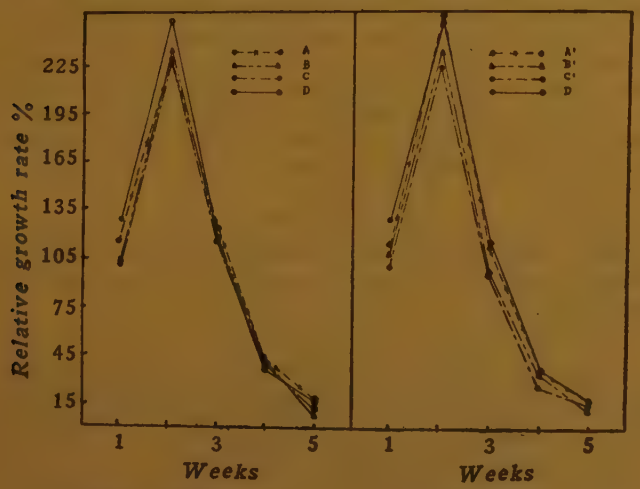
In general, relative growth rate (Fig. 4) increases till it reaches an optimum between second and third week, thereafter there is a sudden fall. The sudden fall in the growth rate seems to be due to the rapid

utilization of some ingredients of the nutrient medium after which the growth rate slows down.

TABLE III

Growth on different liquid media
Temperature 18–20° *C.*

Medium	Dry wt. of the fungus in gm.				
	1	2	3	4	5 weeks
Richard's solution ..	0·036	0·458	1·424	2·051	2·432
Turnip juice ..	0·031	0·405	1·224	1·752	2·075
Potato dextrose solution ..	0·032	0·316	1·087	1·654	1·953
Host twig extract ..	0·028	0·295	0·952	1·442	1·525
Host leaf extract ..	0·028	0·275	0·875	1·275	1·427
Brown's starch solution ..	0·029	0·300	0·789	1·110	1·238
Brown's solution ..	0·027	0·256	0·653	0·846	0·98



A—Potato Dextrose
B—Host twig extract
C—Host leaf extract
D—Richard's solution

A′—Turnip juice
B′—Brown's starch solution
C′—Brown's solution
D —Richard's solution

FIG. 4. Relative growth rate of *Colletotrichum inamdarii* in different liquid media

It has been observed that with the increase in the depth of the medium, growth increases but the fall in the growth rate with time is

greater with the increase in the depth of the medium. This may be casued by the greater production of staling substances with prolonged growth.

The growth of the fungus is greater in alternate light and darkness (88 mm. in diameter) than either continuous light (80 mm. in diameter) or continuous darkness (83·5 mm. in diameter). However, growth in darkness is greater than in light.

Growth of the fungus increases with the increase in temperature of incubation with an optimum at 28°C. after which decrease in the growth results with further increase in temperature.

The cardinal points of pH for growth of the fungus are exactly the same as for the germination of conidia. It should, however, be noted that the fungus whether grown in alkaline or in acidic solution alters the pH value of the medium to neutrality (pH 7).

Constituents of the Medium

It has been found that sugar is the most important constituent for the fungus. Growth is meagre (0·27 gm.*) without sugar in the medium as compared to the control (1·358 gm.*). Of the various carbohydrates, sucrose, glucose, maltose, galactose, levulose and lactose, sucrose is the most suitable form. But other forms of sugar are also used fairly well. Phosphate is another important constituent without which growth is very poor. Next in importance is nitrate. The most suitable form of nitrogen has been found to be sodium nitrate (0·968 gm.*) but other inorganic forms of nitrogen such as ammonium nitrate (0·705 gm.*), ammonium sulphate (0·622 gm.*), and ammonium chloride (0·412 gm.*) are all fairly well utilised. Organic forms of nitrogen such as asparagine (0·915 gm.*) and urea (0·85 gm.*) are better than inorganic forms except sodium nitrate. Sodium nitrate depresses the growth.

Enzymes

Diastase, invertase, protease and laccase have been detected as intracellular and extracellular enzymes following the method of Nutman (1929).

Control

Of the toxic substances tested, 0·1% copper sulphate in aqueous solutions, has been found to check the growth of the mycelium and the germination of the spores. Copper sulphate sprays therefore can be used effectively in cases of severe infection.

Summary

1. A leaf-spot disease of *Carissa carandas* caused by a new species of *Colletotrichum* has been described and named as *Colletotrichum inamdarii* sp. nov.

* Figures indicate the dry weight of the mycelium after 21 days' growth.

2. Pathogenicity experiments have indicated that although a wound parasite it behaves as a normal parasite in host suspension. In nature, exudation from wounds caused by thorns provides stimulation for normal infection.

3. The fungus hibernates in the unfavourable season in the form of the mycelium.

4. Germination of conidia and their method of infection has been described.

5. Physiology and nutrition of the fungus have been studied. Best growth occurs at 27° C. and at neutral reaction of the medium. Sucrose is the best form of sugar and sodium nitrate is the best source of nitrogen.

6. Copper sulphate sprays have been suggested for the control of the disease.

Literature Cited

1. Mundkur, B. B. and Kheshwalla, K. F. 1942. Indian and Burman species of the genera *Pestalotia* and *Monochætia*. Mycologia, 34: 309–17.
2. Dey, P. K. 1919. Studies in physiology of parasitism, infection by *Colletotrichum lindemuthianum*. Ann. Bot. 33: 305–12.
3. ———. 1933. Studies in Appressorium of *C. glæosporioides*. Ann. Bot. 47: 305–12.
4. Nutman, F. J. 1929. Studies of wood destroying fungi, *Polyporus bispidus*. Ann. Appl. Biol. 16: 40–64.

THE OCCURRENCE OF TRI-CARPELLARY GYNŒCIA IN CERTAIN GENERA OF THE RUBIACEÆ

By T. C. N. Singh and S. Kalyansundaram
Department of Botany, Annamalai University, Annamalainagar

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The occurrence of gynœcia with more than two carpels is rather a rare phenomenon in the Rubiaceæ. The genera *Ixora*, *Mussænda* and *Oldenlandia*, for example, are known to be characterized without exception by the possession of bi-carpellary gynœcia. During the course of certain practical classes, however, the presence of tri-carpellary gynœcia was found to be of rather frequent occurrence in these genera. The observations based on plants growing in the Botanical Garden of Annamalai University, Annamalainagar, South India, are described here.

Ixora.—Tri-locular gynœcia were observed in two species, *viz*., *I. coccinia* Linn. and *I. finlaysoniana* Wall. In the latter, in addition, one case of tetra-locular gynœcium was also met with. In each case, when the gynœcium was tri-locular, the style was topped by a tri-fid stigma. Similarly the tetra-locular gynœcium had style topped by a tetra-fid stigma (Figs. 1 and 2), showing thereby that the gynœcia were

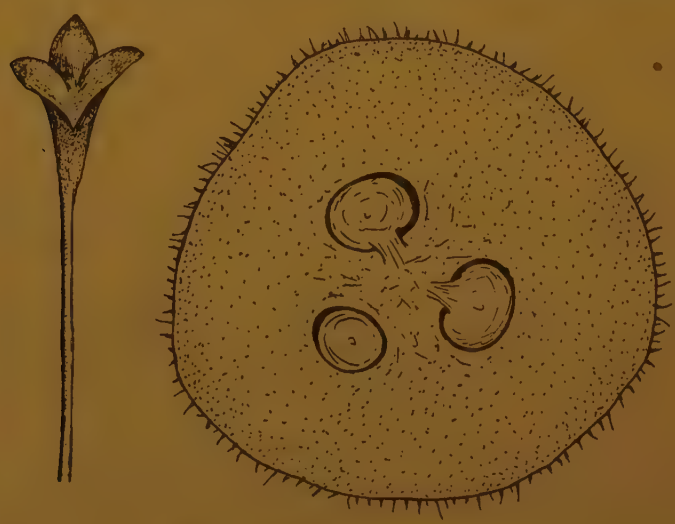


Fig. 1. *Ixora coccinia* L., showing the tri-locular gynœcium (×366·66) and its style with three-fid stigma (×13·33).

respectively tri- and tetra-carpellary. From a statistical study of the flower counts, it was found that the percentage occurrence of the tri-carpellary gynœcia was 4 per cent. in *Ixora coccinia* Linn. and 2 per cent. in *I. finlaysoniana* Wall.

FIG. 2. *Ixora finlaysoniana* Wall., showing the tetra-carpellary gynœcium (×366·66) and its style with four-fid stigma (13·33×).

FIG. 3. *Mussænda frondosa* Linn., showing the tri-locular gynœcium (×366·66 and its style with three-fid stigma (×13·33)

Mussænda frondosa Linn.—In this case, tri-locular and tri-carpellary gynœcia were found to the extent of 2 per cent. In each such case, here also the style was topped by a tri-fid stigma (Fig. 3).

Oldenlandia umbellata Linn.—Tri-carpellary gynœcia to a frequency extent of 2 per cent. have been observed in this species also, with the difference that the stigmas are not very clearly tri-fid.

The occurrence of tri-carpellary gynœcia in *Ixora*, *Mussænda* and *Oldenlandia* in such high proportions should not be surprising ; as in several other genera of the Rubiaceæ, *e.g.*, *Fergusonia*, *Anotis*, *Adenosacme* etc., gynœcia have ordinarily more than two carpels. It appears to be quite natural to expect such aberrations because the family Rubiaceæ is closely related to families like *Caprifoliacea*, *Adoxaceæ*, *Valerianaceæ* and *Campanulaceæ*, where also the gynœcia are often composed of more than two carpels and the tri-carpellary condition is common.

ACKNOWLEDGEMENT

I am grateful to Professor Oswald Tippo of Urbana (Illinois) for his useful suggestions and to the members of the Botany Department Research Club of the Annamalai University for their critical discussions during the weekly Friday Meetings of the Club.

A *CODIUM* FROM THE COROMANDEL COAST

By T. Sreeramulu

Department of Botany, Andhra University, Waltair

(Received for publication on December 15, 1952)

Introduction

Four species of Codium were reported from India by Boergesen (1930, 1937) and Anand (1940), namely *Codium tomentosum*, *C. elongatum*, *C. coronatum*, and *C. latum*, from the shores of the presidency of Bombay and Krusadai islands. Later Boergesen (1946) reported two new species, *C. Iyengarii* and *C. dwarakense*, from the Arabian Sea near the shores of Dwaraka and Okha. Recently the writer (1952) reported the occurrence of the former species on the east coast north of Krusadai islands. Boergesen's description of this species was based on a specimen, preserved in alcohol, collected from Cape Monze near Karachi, which was not fertile and was incomplete. As the plants collected at Waltair contain many gametangia, it has been considered worthwhile to complete the description of this species.

Description

The plants described were collected in February 1952 near Waltair. They are not very common and have not been collected from more than one locality. They are firmly attached to rocks, which, except when there is extremely low tide, are not exposed.

The plants are dark green in colour and have an uneven, dotted surface owing to the presence of large scattered vesicles. The plants

Fig. 1. Habit of a specimen (Double the natural size).

are regularly branched dichotomously with a distance of about 1 cm. between the divisions. The thallus is cylindrical, flabby with a diameter of about 3–4 mm., being a little broader just below the divisions (Fig. 1). It is composed of a central medulla of narrow, interwoven, dichotomously branched threads with mucilagenous septa, characteristic of Codiaceæ and a peripheral cortex of large vesicles densely grouped at the same level to form a palisade layer. The filaments which constitute the central medulla vary in size from 40–60 μ in diameter. The vesicles which constitute the cortex greatly vary in shape, ranging from broadly clavate to barrel-shaped (Fig. 2). The size of the vesicles varies with age, their breadth ranging from

Fig. 2. Vesicles with hairs and gametangia (×150).

150–500 μ and length from 650–1,100 μ. The tip of the vesicles in the younger stages are vaulted, but in the older ones they are flat. The broader vesicles have always a flat or even a little depressed apical ends. The apical wall is quite thin. As the larger vesicles are distributed among the smaller ones, the apices of these stand out on the

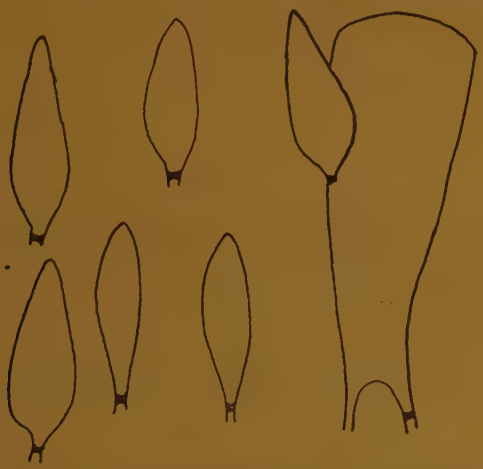


FIG. 3. A vesicle with a gametangium and 5 other gametangia (×150).

surface as dots. Hair production is not abundant, but some hairs are given out from the upper sides of the vesicles.

The gametangia (Fig. 3) arise as lateral outgrowths from the vesicles, from which they are cut off by mucilaginous septa. They are spindle-shaped, 200–350 μ long and 70–150 μ broad.

In conclusion, I wish to express my grateful thanks to Prof. J. Venkateswarlu for encouragement and to Mr. B. S. Sivarao for help in preparation of this paper.

LITERATURE CITED

ANAND, P. L. 1940. Marine Algæ from Karachi. Part I. Punjab University, Lahore.

BOERGESEN, F. 1930. Some Indian green and brown algæ especially from the shores of the Presidency of Bombay. J. Indian bot. Soc., 9: 151–174.

————. 1937. Contribution to a South Indian marine algal flora. J. Indian bot. Soc. 16: 1–56.

————. 1946. Remarks on some *Codiums* from the Arabian sea. J. Indian bot. Soc., Prof. M. O. P. Iyengar Comm. Vol. 1–9.

FRITSCH, F. E. 1935. The structure and reproduction of the algæ. Vol. 1. Cambridge University Press.

Sreeramulu, T. 1952. Occurrence of *Codium* on the Coromandel coast. Curr. Sci. 21: 114.

MEGASPORES AND OTHER PLANT REMAINS FROM LOWER GONDWANA OF SINGRAULI COALFIELD, DISTRICT MIRZAPUR, U.P.

By B. S. Trivedi
Botany Department, Lucknow University

(Received for publication on October 10, 1952)

Introduction

Microspores (Ghosh and Sen, 1948; Mehta, 1942 and 1943; Sitholey, 1943; and Virkki, 1945) and pollen grains (Bose, 1950; Rao, 1936; and Rao and Vimal, 1950) have received far larger attention in this country than the megaspores; there are very few studies of the latter.

Mehta (1942) in his investigations on the microspores from shales of Mirzapur mentions, "Three megaspores (319–388μ) with triradiate marks and warty or granular surface", but these have been neither figured nor fully described. Later, Mehta (1943) published a photograph of a megaspore, but the description was very meagre. The spore is given no name, and no relationship has been established. Sitholey (1943 and 1943 *a*) discovered a large number of megaspore casts from the Triassic of Salt Range, Punjab, which he named as *Triletes Sahnii*. Saxena (M/S) has recorded a few megaspores probably from the Lower Gondwana of South Rewah, Central India, but the details of his studies have not been published so far. From the Dhekiajuli beds of Assam (? Upper Miocene or ? Lower Pliocene) Sahni *et al.* (1947) figure without any description a single megaspore (265μ). Ghosh and Sen (1948) have figured a few bodies about whose affinities (p. 85) they are doubtful (pl. 13, figs. 128, 129, pl. 14, figs. 130, 131, 132, 136; etc.) but from the figures some of them appear to me to be megaspores. Pant (1950) has recovered megaspores from "A micaceous shale from Talchir coalfield (exact horizon not known)." I (Trivedi, 1950) have found a large number of megaspores in some coal samples of Barakar age collected from Singrauli coalfield by Dr. R. C. Misra of Geology Department of this University, as also in a few samples kindly supplied by the Geological Survey of India. The present paper is based on a detailed study of these.

Material and Method

Macerations were first carried out with Schulze's solution followed by weak ammonia for clearing. Most of the megaspores so treated appeared mutilated. Schulze's solution proved a very strong oxidising agent; consequently as soon as ammonia was applied, the megaspores swelled and some of them completely disorganised. This process could be observed under a microscope. Megaspores are the least

resistant to oxidation, woods and cuticles are a little more and microspores appear to be the most resistant.

In the light of this experience, and at the suggestion of Prof. T. M. Harris, pure concentrated HNO_3 (65·3%) at room temperature in winter was substituted for Schulze's solution. Even this proved a very strong oxidising agent during summer months. Each sample prior to maceration was thoroughly washed, sometimes it was soaked in water for 24 hours or more and then kept in HNO_3. Each sample requires a different maceration period but during winters, at room temperature, most of the samples needed 2 to 3 days. After maceration, each sample was thoroughly washed in running water for 4–5 hours; then freshly prepared 10% NaOH solution was added; the sample was kept in alkali for about 10 hours. In order to test the efficacy of alkali treatment, in a few samples no alkali was used, megaspores thus obtained were opaque and had a large number of carbon particles adhering to them. The use of alkali makes the megaspores more transparent, and all adhesions disappear. NaOH was preferred to NH_4OH because it is more handy to use and secondly it has no offensive smell.

After alkali treatment, each sample was very thoroughly washed so as to completely remove even the last traces of it. Such a sample was then passed through standard sieves. Each fraction was separately collected and examined.

The best way to pick out megaspores from such fractions is to spread a small quantity in a Petri dish, half full of water underneath which is placed a piece of white paper. The sample is aggregated on one side of the dish leaving the major portion of the Petri dish with water alone. The dish is slightly tilted at 3–5° and kept in this position so that the sample side is higher up and water side downwards. Now, by means of a dropper a slow current of water from sample side towards the empty area is generated. The particles disperse; because of the presence of a white background it is possible to distinguish between the absolutely black objects and dark orange or chocolate coloured, spherical megaspores. These can be easily separated out. This method is simple and quick. The eye has not to be exercised too much by looking constantly into a binocular for searching the megaspores. Even small megaspores and their broken pieces could thus be picked out. A few samples from which the megaspores were thus picked out, did not reveal any megaspores when observed under a binocular microscope.

Material not for immediate use was stored in 90% alcohol and 50% glycerine, mixed in equal proportions. Megaspores to be described were dehydrated, and mounted in Balsam. A few megaspores were mounted in hollowed slides also, but as no proper light reflecting arrangement was available this method for their study was not pursued. All the specimens described below were mounted as flat objects in Canada Balsam.

Glycerine jelly was also used but without a hardener it did not prove a success. It was, therefore, given up.

The coal samples are extremely rich in megaspores. 4½ gms. of coal yielded nearly 430 megaspores, thus giving a ratio of about 95 megaspores per 1 gm. of coal, besides numerous other microfossils.

The megaspores have only the exospore, no endospore was found. A large number of microtome sections of megaspores were cut, these were mounted in glycerine jelly and stained with methyl green (Wodehouse, 1935). Not even in one case was an endospore present. The exosporium takes up a bright green stain.

All the megaspore specimens are, for the present, with the author.

Locality

The sample of coal was collected by Dr. R. C. Misra from a thin seam of coal, exposed in a small rivulet north of Kotah (24° 6′–82° 45′); district Mirzapur, U.P. Age (Lower Gondwana), probably Barakars. The Geological Survey of India samples also came from a locality very near to this one.

Description

Sectio Aphanozonati Schopf.

Triletes kotahensis sp. nov. (Text-Fig. 1; Pl. III, Photo 1)

Spores small varying from 700 μ to 1 mm. in diameter; one of the spores is 679 μ long and 590 μ broad; round or oval, folds numerous. Contact areas distinct (a portion of one of the sectors is broken); these occupy about 55% of the proximal half of the flattened spore by planimetric measurements. Surface finely rugose-granulose; light to dark brown by transmitted light. Spore coat 10–12 μ thick, suture closed, lip not seen, suture line 284 μ long, 16·6 μ high and 37·5 μ broad. The distal portion of the spore is ornamented with small indistinct punctations.

The distinguishing features of these spores are (1) long radii of the suture lines in proportion to the spore diameter, and (2) granulose-rugose ornamentation on the proximal half of the spore.

Triletes granulosus sp. nov. (Text-Fig. 2; Pl. I, Photo 2)

Spores round or slightly oval; 950 μ long, 900 μ broad; surface granulose, folds may be present. Suture lines about 242 μ, long 370 to 75 μ high and about 16 μ broad, closed, lip not seen, spore coat 8 μ but is difficult to measure in optical section. Arcuate ridges and contact areas indistinct, but shown by dotted line in (Text-Fig. 2). The trilete like mark (S.C.) shown in the photograph and (Text-Fig. 2) is the ruptured spore coat. Distal portion a little more distinctly ornamented than the proximal. Spores light to dark brown in transmitted light.

This species differs from *T. kotahensis* sp. nov. in having (1) a thin spore coat, (2) indistinct arcuate ridges and contact areas, and (3) smaller suture lines, in proportion to the total spore diameter. These features also constitute its distinguishing characters. As this

TEXT-FIGS. 1–5.—Fig. 1. *Triletes kotahensis* sp. nov., ×82. Fig. 2. *Triletes granulosus* sp. nov., the ruptured exine (*s.c.*) simulates suture lines, ×82. Fig. 3. *Triletes* sp., ×82. Fig. 4. Papillæ of above as seen in the surface view, ×490. Fig. 5. Papillæ of above as seen in the optical section, ×490.

form is very distinct, it could not be even compared with any other known form, it is, therefore, placed in a new species.

Triletes sp. (Text-Figs. 3, 4 and 5; Pl. III, Photo 3)

Spore 1·22 mm. in diameter, surface finely granular and papillate; suture lines not seen; but judging by its size, it appears likely to belong to the genus *Triletes*. Contact areas and arcuate ridges not preserved, spore flattened and crushed.

Papillæ broader than tall; they are 20–32 μ broad and 10–12 μ high. In some of the papillæ a somewhat dark central portion may

be seen. Although this spore superficially resembles *T. brevispiculus* Schopf, yet the two differ from each other in the following characters:

(1) The structure and the size of papillæ, and

(2) *T. brevispiculus* Schopf is larger in size than the present spore.

It resembles *T. mamillarius* Bartlett in that in some forms within this species the papillæ are broader than tall.

Due to bad preservation this spore has not been given a specific name. Spore coat dark orange and thick.

Triletes singraulensis sp. nov. (Text-Figs. 4 and 5; Pl. III, Photos 4 and 5, Pl. IV, Photo 6)

Spores large on the average measure 765 μ long, 658 μ broad, ornamented, round (Pl. III, Photo 4) or oval (Pl. IV, Photo 6) a few spores are slightly damaged, with or without small folds. Contact areas occupy about 60% (Text-Fig. 6; Pl. III, Photo 5) of the total flattened spore area (Planimetric measurements). Surface dark brown in transmitted light, with numerous papillæ (Text-Fig. 8). Spore coat, deep yellow to dark-brown; 10–12 μ thick.

Sature lines about 200 μ long, 27·5 μ high, and 33·2 μ broad, suture split open. The surface of the spore near the lip and also the trilete suture is thrown into folds (Text-Fig. 7). Arcuate ridges prominent, sculpturing verrucose; dense on the distal side, sparse on the proximal; apeculi 10 μ broad at the base and 10 μ high.

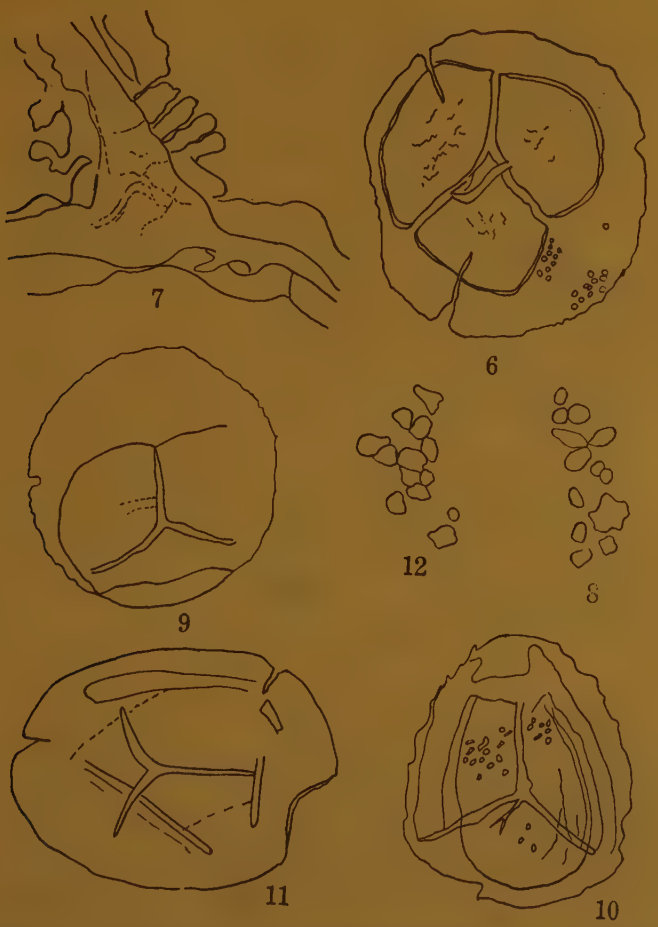
This spore differs from *Trilete* sp. (Pl. III, Photo 3) in that the latter has apeculi which are, (1) broader than tall and (2) the apeculi are uniformaly distributed over the entire surface of the spore. In the present spore the apeculi are as broad as high and are unevenly distributed over the two hemispheres of the spore.

This spore may be compared to *T. brevispiculus* Schopf in being papillate but differs from it in the size of the spore itself and those of the papillæ.

A few spores of almost the same shape and size but without well defined sculputre have also been found. These for want of other differences have been placed under this species. It may be possible to separate them later.

Triletes elongatus sp. nov. (Text-Figs. 10, 11, 12 and 13; Pl. IV, Photos 7 and 8)

Spores ornamented, shape varying, oval to elongate, 790 μ long 600 μ broad, folds present, (Text-Fig. 10, Pl. IV, Photo 8), suture closed and well preserved, longest suture lines 200 μ, the two smaller 145 μ each, arcuate ridges, and contact faces not preserved. Spore coat 8 μ thick, dark-brown, covered over by numerous papillæ (Text-Fig. 13) irregularly shaped, and somewhat ill-defined. This spore differs from the others in having a variable shape, a thin spore coat and in having a characteristic ornamentations. It is, therefore, placed as a new species.



TEXT-FIGS. 6–12.—Figs. 6 & 9. *Triletes singraulensis* sp. nov.—The two types of spores constitute only one species, ×82. Fig. 7. A small part of suture of above enlarged, ×490. Fig. 8. Some of the papillæ of above enlarged, ×490. Fig. 10. *Triletes elongatus* sp. nov., ×80. Fig. 11. *Triletes elongatus* sp. nov., ×95. Fig. 12. Some of the papillæ of Fig. 10, enlarged, ×490.

Triletes papillarius sp. nov. (Text-Figs. 14, 15, 16 and 17; Pl. V, Photo 17)

Spores slightly oval or round in shape, 543 μ long, 458 μ broad, folds absent, suture lines well preserved; unequal, longest about 198 μ, the two shorter 141 μ each. At the junction of the three lines is present an expanded lobular area which may have been raised like a protuberance as in *T. prætextus* Zerndt, although here it appears to be flat, 213·5 μ. Arcuate ridges indistinct, contact areas clearly defined, occupying about 40% of the total spore area (in planimetric measurements). Spore coat dark-brown, 18 μ thick, ornamentation dense and

TEXT-FIGS. 13–21.—Fig. 13. Ornamentation of *T. elongatus* sp. nov. from the area marked on the spore, enlarged, ×490. Fig. 14. *Triletes papillarius* sp. nov., ×82. Fig. 15. Papillæ, from the area marked 3 on the spore, enlarged, ×490. Fig. 16. Papillæ of *T. papillarius* sp. nov. from the area marked 2, enlarged, ×490. Fig. 17. Papillæ of above from the proximal hemisphere, marked 1 in Fig. 14, enlarged, ×490. Fig. 18. *Triletes brasserti* Stach et Zerndt, ×82. Fig. 19. As above, an overmacerated specimen, ×90. Fig. 20. *Triletes punctatus* sp. nov., the dark pellet is (?) an abortive spore, ×82. Fig. 21. Ornamentation of above, from the triangular area marked in Fig. 20, enlarged, ×490.

crowded, consisting of numerous sinuous or elongate papillate structures (Text-Figs. 15, 16 and 17). Most papillæ are simple elongate projections while others are composed of two or three projections with the central one slightly higher than the rest. The papillæ at the base measure from 8 μ to 22·4 μ in breadth, and 8 μ in height. Contact areas as also the distal portion of the spore, is densely ornamented.

The ornamentation of the spore is characterised by the presence of numerous crowded papillæ, these occur on the proximal side also.

This character makes this species very distinct. It may be compared to *T. prætextus* Zerndt, in having the junction area between the three suture lines raised but differs from it in that the proximal prominence is not so well marked as in the former. The spore on the basis of these characters is given a new specific name, *viz.*, *Triletes papillarius* sp. nov.

Sectio Lagenicula (Binnie and Kidston) Schopf.

Triletes punctatus sp. nov. (Text-Figs. 20 and 21; Pl. IV, Photo 12)

Spore preserved flat, 0·806 mm. long exclusive of neck and ·72 mm. broad, neck 0·194 mm. long and broad. Ornamented on distal side only; the proximal side is completely devoid of ornamentation. Suture lines not seen; punctæ well preserved, 12·8 μ in breadth and 11·2 μ in height, not very dense, and do not pass beyond the posterior region. On the proximal side is present a dark carbonaceous pellet probably representing one of the abortive spores. Another hollow area contiguous to it may have lodged a second abortive spore. The spore is yellow in colour, and is thin walled.

Dijkstra (1946) believes that *Triletes rugosus* (Loose) Dijkstra *emend*, is constituted by three types of spores, his third type (p. 48, pl. 10, Figs. 104–107) approaches in size the present spore, but differs considerably in spore coat thickness and in punctations. His other two types do not resemble this spore at all. Therefore, although, only a single spore has been found yet because of its sufficiently well characterised features, it has been placed in a distinct species; viz., *Triletes punctatus* sp. nov.

Triletes sp. (Text-Fig. 22, Pl. IV, Photo 11)

Spore 1·94 mm. long, 1·74 mm. broad at the broadest point. Trilete suture and arcuate ridges not seen. Spore smooth, spore coat 20–22 μ thick. On the surface of some of the spores are present a few folds, sometimes numerous carbon particles are also adhering. Preservation is poor. In size, shape and the characters of the spore coat this spore shows some resemblance to *Triletes nudus* (Nowak et Zerndt) Schopf; Schopf *et al.* (1944).

Secto Triangulatæ Schopf.

Triletes brasserti Stach and Zerndt. (Text-Figs. 18 and 19; Pl. IV, Photos 9 and 10)

Average diameter of the spores varies from 455 μ to 572 μ (inclusive of equatorial flange); hemispherical or when pressed slightly triangular in shape. Suture lines well preserved, undulating, joining the arcuate ridges, occasionally as long as the diameter of the spore or shorter; 14 to 14·5 μ high.

Proximal and distal areas densely or sparsely granulose or papillose (ornamentation varies considerably within this species). Spore coat 12–16 μ thick, flange rugose, cannot be made out in many spores.

This spore is extremely common and occurs abundantly. It differs from the typical *T. brasserti* Stach and Zerndt (1934) in being a little

smaller and in not having a very pronounced equatorial flange. Further, in my specimens it does not separate out as stated for the type specimen (Dijkstra, 1950: 869).

Cystosporites Schopf.

Cystosporites indicus sp. nov. (Text-Figs. 23 and 25; Pl. V, Photos 14 and 15)

Spores large, smooth, round 2·6–2·8 mm. in diameter, or oval 2·2 by 1·75 mm. Sac-like, arcuate ridges and suture lines not well

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TEXT-FIGS. 22–24.—Fig. 22. *Triletes* sp., ×40. Fig. 23. *Cystosporites indicus* sp. nov. The area between the two outermost layers represents the membrane, ×40. Fig. 24. *Sporangium A*, with contents, ×40.

preserved, abortive spores sometimes present. Some of these occur in association with the larger spores either detached or in organic

connection (Text-Fig. 25; Pl. V, Photo 15) one of the arcuate ridges can also be seen.

Spore coat plain and smooth, never fibrous as mentioned by Schopf, this spore coat is divisible into two definite zones, *viz.*, (1) The outer membranous transparent "Wing-like outgrowth of the exospore" (Bochenski), and (2) the inner thick dark orange transparent to opaque membranous structure. The distal surface of the spores is almost opaque, the proximal area is more or less transparent.

"The wing-like outgrowth" is not continuous throughout the entire body of the spore but is present only towards the proximal side of the spore and is missing from the distal side (Text-Fig. 25; Pl. V, Photo 15).

In those spores which are flat and round due to preservation this "wing-like outgrowth" can be seen going round only upto about three-fourths of their circumference (Text-Fig. 23; Pl. V, Photo 14) and then stopping short. This "outgrowth" may or may not be prominent. It is probably proximal but this fact could not be definitely ascertained.

The one attached abortive spore (Text-Fig. 25; Pl. V, Photo 15), is opaque and shows no reticulation, while a few unattached ones lying on the surface of the bigger spores show reticulations. Abortive spores measure 240 μ by 210 μ.

Cystosporites indicus sp. nov. differs from the *C. breretonensis* Schopf, in the following characters:

(1) The presence of a well defined and probably a proximal "wing-like outgrowth".

(2) The spore coat is not fibrous; it is plain and smooth.

(3) This spore is smaller in size than *C. breretonensis* which is 4–10 mm. long whereas this one is only 2·6 to 2·8 mm. long.

Species of *Cystosporites* described and figured by Dijkstra (1946) also differ from this species in characters 1 and 3 given above. It is difficult to correctly judge the relative merit of these characters. Probably the spore in question may represent a new genus but until more is known I would place it under genus *Cystosporites* Schopf. It is certainly a new species. I, therefore, propose to name it *Cystosporites indicus* sp. nov.

Cystosporites indicus sp. nov. occurs in abundance in these coal samples.

Cystosporites sp. (Text-Fig. 26)

Spores 3·4 mm. long, 1·7 mm. broad, smooth; no suture lines or arcuate ridges preserved, only elongate in shape, none of them are round. To some of them, dark abortive spores 237 μ by 140 μ are attached. "Wing-like outgrowth" absent, the spores are not sufficiently well preserved to deserve a specific name, therefore, no name

TEXT-FIGS. 25–27.—Fig. 25. *Cystosporites indicus* sp. nov., showing (?) an abortive spore and the membrane, ×40. Fig. 26. *Cystosporites sp.* with an abortive spore, ×40. Fig. 27. Basal portion of sporangium B, enlarged, ×90.

is given. They differ from *C. indicus* sp. nov. in the absence of "wing-like outgrowth" and (2) in that all of them are preserved as elongated bodies, none of them are round. The characters by which this form is separated from *C. indicus* sp. nov., do not seem to be very dependable but in the absence of any other criteria these are presumed to be satisfactory. This form is, therefore, kept as a separate species but because the characters are not well defined, a specific name has not been given.

SPORANGIA

Two or three sac-like structures have been discovered. In one of them can be seen an ? immature megaspore; in the other two no

contents are seen. It is likely that they may be sporangia but their nature is not correctly understood.

Sporangium A (Text-Fig. 24, Pl. V, Photo 16)

Elongate, 1·45 mm. by ·758 mm.; coat smooth and wrinkled. Enclosed within it is a dark brown body, 970 μ by 679 μ, it shows a large number of small wrinkles which may be only accidental folds or may be the beginnings of spore sculpture.

Sporangium B (Text-Figs. 27 and 28)

An elongated body 2·66 mm. by 1·64 mm. The sporangium has thin outer transparent wall, which is darker than the outer one.

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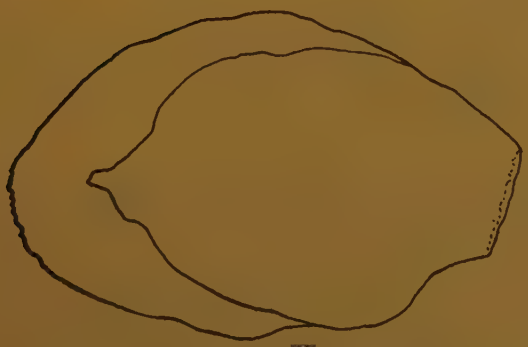

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TEXT-FIGS. 28–29.—Fig. 28. Sporangium B, ×40. Fig. 29. Sporangium C, ×40.

At one of the ends, probably basal (Text-Fig. 27), the cells of the outer membrane are modified, the inner membrane has a small projection towards this side; the other end is flat. The outer and inner membranes are distinct and separated from the basal portion to about the middle of the sporangium after which the two can no longer be seen separately. The outer membrane in texture shows a resemblance to the "wing-like outgrowth" of *Cystosporites indicus* sp. nov.

Sporangium C ? (Text-Fig. 29)

This resembles sporangium B but is more elongate. It is 2·75 mm. by 1·45 mm. At one of the ends of the sporangium the outer membrane is more prominent, and continues from this extremity to the other without disappearing as in sporangium B. Cells of neither extremity show any modification. This sporangium is, therefore, separately placed.

Incertæ Sedis (Pl. V, Photo 13)

A large, smooth and oval body with neither suture lines nor arcuate ridges, 1·45 mm. to 1·94 mm. long and 1·21 mm. to 1·64 mm. broad. Wall 15 to 16 μ thick; surface is slightly wrinkled (sometimes with folds). One specimen appears as if it has dehisced. Characteristic features of this body are (1) its large size, (2) its smooth exine, and (3) its oval shape. It is also characterised by the absence of suture lines. Probably a seed; affinities obscure.

Discussion and Original Observations

Schopf (1938: 17–24) employed the generic name *Triletes* for fossil megaspores with a triradiate mark, which probably belonged to Lycopodiales. *Triletes* has been used in the same sense here also. I consider the presence of clear suture lines as an important character of *Triletes* because otherwise the megaspores of some Hydropterideæ —where this mark in the mature spore is generally obscure—can be classified under section *Lagenicula* of the genus *Triletes* and thus the phylogenetic significance of this genus may be lost.

Dijkstra (1948) has figured and described a megaspore *Triletes lobatus* Dijkstra which to me appears to resemble a megaspore of *Regnellidium* in shape and size and as the suture lines are obscure the resemblance becomes all the more closer. I feel that this megaspore should not be placed under *Triletes* as it does not possess the suture lines.

The vestibule of the Lageniculate megaspores also needs a thorough investigation as it is only imperfectly known. Perhaps it may show some characteristic diagnostic features.

Lycopods in the form of impressions or petrifactions are almost completely absent in the Palæozoic of India with the single exception of a Permian, *Bothrodendron*, (Sahni 1922, Table 2). Our knowledge of fructifications of *Glossopteris* and other allied plants is almost negligible. Therefore, the possibility that some of them could bear spores similar or identical to *Triletes* cannot be absolutely ruled out. According to Schopf (1938: 22), however, the information which has accumulated, only serves to emphasize the relationship of the *Triletes* with the Lycopodiales. I fully share this view. The presence, therefore, of a large number of megaspores, *Triletes spp.*, from the Barakars of Singrauli coalfield strongly suggests the presence of Lycopods in the Palæozoic beds of India. Mehta (1943) also has reported the presence of some *Trilete* spores in the shales of this area. Further, Saxena (M/S) and Pant (1950) have found *Triletes spp.* in Karharbari and

Talchir stages, respectively, from different parts of India. In the light of these finds it can be safely assumed that the Lycopods existed in the Palæozoic of India.

The spatial separation of *Glossopteris* flora on the one hand and flora dominated by *Lepidodendron* and *Sigillaria* on the other, is almost taken for granted (Fox, 1931: 70–77). It is also sometimes suggested that the passage of time permitted a comingling of the two floras in South America in the Upper Palæozoic times. In the light of evidence (*vide* supra) the co-existence of these two floras in the Palæozoic of India is evident. Their co-extension from Talchir to Karharbari and thence to Barakars (Lr. Permian) is also shown. We thus find a consistent and co-extensive record of the *Glossopteris* and *Lycopodiales* from the upper Carboniferous to Lower Permian of India.

While defining the genus *Cystopsorites* Schopf *et al*, (1944: 40) lay stress on the fibrous aspect of the spore coat of these specimens. My specimens have a smooth sporecoat with two distinct zones, but. otherwise resemble those figured and described by Schopf. This difference perhaps does not warrant a generic separation. I have, therefore, included my specimens within the genus *Cystosporites*. Due to the difference in spore coat and because of their smaller size, I have separated my spores from *C. breretonensis* Schopf, and placed some of them under *C. indicus* sp. nov., while a few forms which could not be accommodated here, have been separated, but as these are not sufficiently well preserved no new specific name has been given.

The presence of *Cystosporites* in the Barakars [Lower Permian] (Wadia, 1939: 130) is not only interesting in itself but it also shows that this genus was not confined to Carboniferous as suggested by Schopf *et al.* (1944) but extended to Lower Permian as well. This is also the first record of the genus from this country.

Summary

(1) *Triletes kotahensis* sp. nov.
(2) *Triletes granulosus* sp. nov.
(3) *Triletes* sp.
(4) *T. singraulensis* sp. nov.
(5) *T. elongatus* sp. nov.
(6) *T. papillarius* sp. nov.
(7) *T. punctatus* sp. nov.
(8) *T.* (*Lagenicula*) sp.
(9) *T. brasserti* Stach et Zerndt.
1. *Cystosporites indicus* sp. nov.
2. *Cystosporites* sp.

A, B, C, three types of sporangia and a doubtful seed have been described in this paper.

The high proportion of new species is significant.

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Bibliography

Arnold, C. A. 1950. Megaspores from Michigan Coal Basin. Contr. Mus. Palæont. Univ. Mich., **5** (5): 59–111.

Bose, M. N. 1950. Angiospermic remains from Barmer Sandstones. Curr. Sci. 18: 246–47.

Cross, A. T. 1947. Spore floras of the Pennsylvanian of West Virginia and Kentucky. Journ. Geol. 4: 285–308.

Dijkstra, S. J. 1946. Eine monographische bearbeitung der karbonischen Megasporen, etc. Med. Geol. Stichting, Serie C III–1, No. 1: 1–101.

———. 1948. Megaspore and some other fossils from the Aachenian (Senonian) in South Limburg, Netherlands. Med. van de Geol. Stichting. Nieuwe Serie No. 3: 19–32.

———. 1950. Carboniferous megaspores in Tertiary and Quaternary deposits of S.-E. England. Ann. Mag. Nat. Hist. 3, Ser. 12: 865–76.

Fox, 1931. The Gondwana system and related formations. Mem. Geol. Surv. India. 58: 1–241.

Ghosh, A. K. and Sen, J. 1948. A study of microfossils and the correlation of some productive coal seams of the Raniganj coalfield, Bengal, India. Trans. Ming. Geol. Met. Inst. of India. 43 (2): 67–95.

Krishnan, M. S. 1943. Geology of India and Burma. Madras.

Mehta, K. R. 1942. Palæobotany in India, III. J. Indian bot. Soc. 21 (3 & 4): 218.

———. 1943. Palæobotany in India, IV. J. Indian bot. Soc. 22 (2, 3 & 4): 173 (pl. 7, fig. 19).

Pant, D. D. 1950. Microfossils in a micaceous shale from the Talchir coalfield. Palæobotany in India, VII. J. Indian bot. Soc. 29 (1): 15.

Rao, A. R. 1936. Winged pollen from the Jurassic of India. Proc. 23rd Ind. Sci. Congr. Indore. 304.

——— and Vimal, K. P. 1950. Plant microfossils from Palana Lignite (? Eocene), Bikaner. Curr. Sci. 19: 82–84.

Sahni, B. 1922. The present position of Indian Palæobotany. Pres. Add. to Bot. Sec. Proc. As. Soc. of Bengal (N.S.). 17: 152–75.

——— *et al.* 1947. Correlation of the Tertiary succession in Assam by means of microfossils. Palæobotany in India, VI. J. Indian bot. Soc. 26 (4): 262 (pl. 17, fig. 47).

Saxena, S. D. Ph.D. Thesis (M/S).

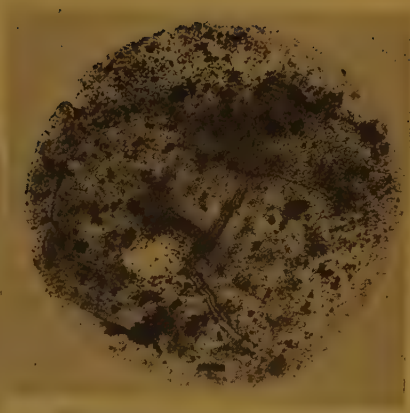
Schopf, J. 1938. Spores from the Herrin (No. 6) coal bed in Illinois, III. Geol. Surv. Rept. Inv. 50: 1–73.

———, Wilson, L. R. and Bentall, R. 1944. An annotated synopsis of Palæozoic fossil spores and the definition of Genetic groups. III. Geol. Surv. Rept. Inv. 91: 1–66.

Schopf, J. 1949. Research in coal Palæobotany since 1943. Econ. Geol. 44 (6): 492–513.

Sitholey, R. V. 1943. *Triletes Sahnii* sp. nov. Palæobotany in India, IV. J. Indian bot. Soc. 22 (2, 3 & 4): 175 (Pl. 6, Figs. 13–16).

———. 1943 *a*. Plant remains from the Triassic of the Salt Range in Punjab. Proc. nat. Acad. Sci. India. 13 (5): 300–27.



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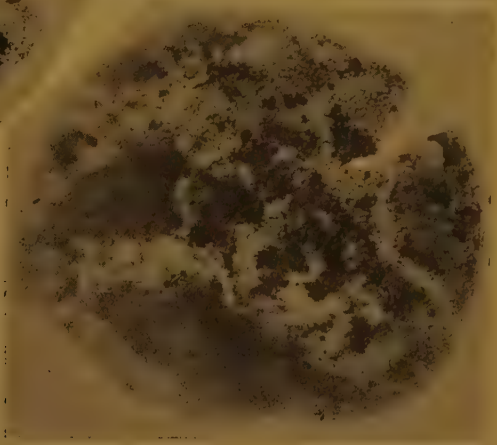

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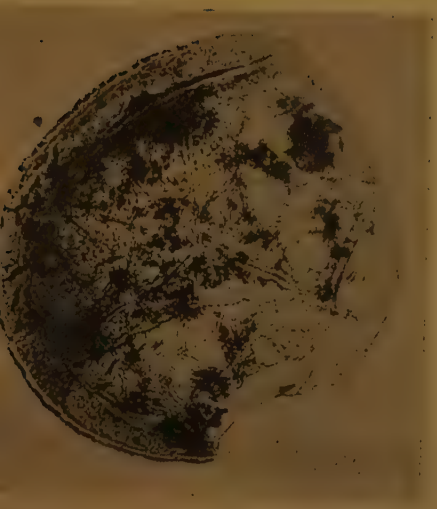

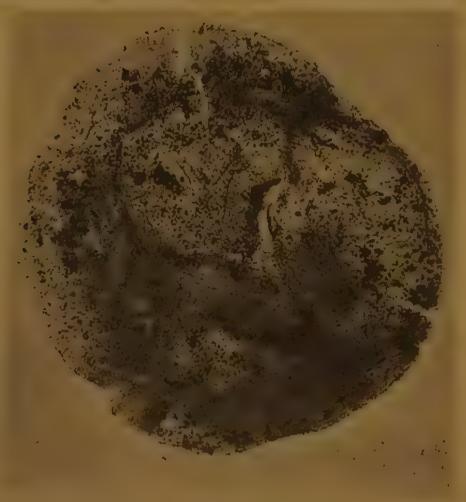

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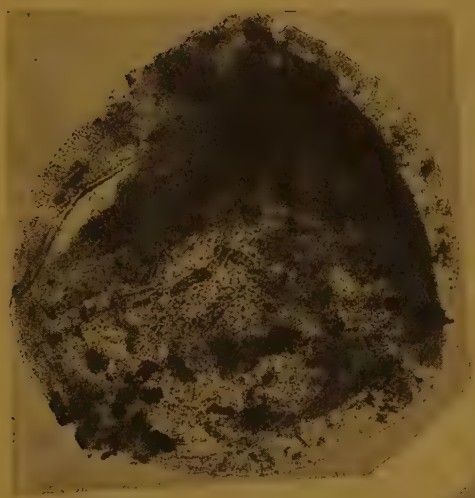

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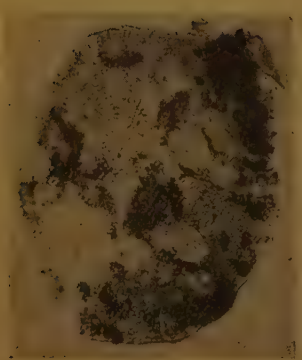

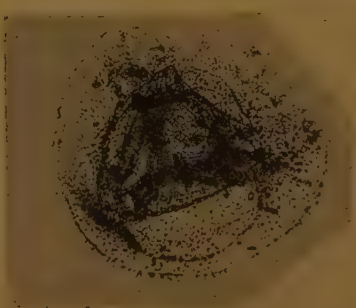

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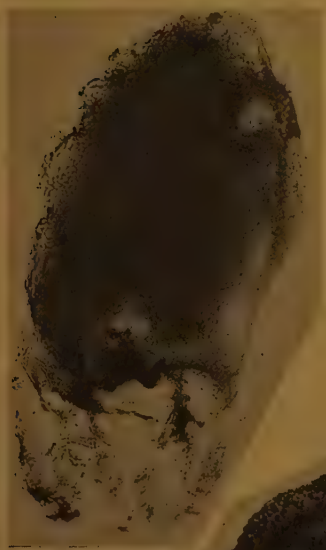

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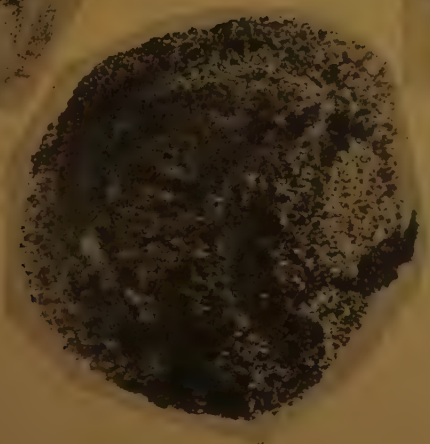

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TRIVEDI, B. S. 1950. Megaspores from Lower Gondwana of Singrauli coal field, District Mirzapur. Curr. Sci. 19: 126.

VIRKKI, C. (Mrs. C. Jacob). 1945. Spores from Lower Gondwana of India and Australia. Proc. Nat. Acad. Sci. India 15 (4 & 5): 93–176.

WADIA, D. N. 1939. Geology of India: 130. Macmillan & Co.

WODEHOUSE, R. P. 1935. Pollen grains. McGraw Hill.

ZERNDT, J. 1934. Les Mégaspores du Bassin Houiller Polonais, Partie 1. Acad. Pol. des. Sci. et des. Lett., Trav. Géol. No. 1: 1–55.

EXPLANATION OF PLATES

PLATE III

Photo 1. *Triletes kotahensis* sp. nov.—Suture lines are clearly visible, ×88.

Photo 2. *Triletes granulosus* sp. nov.—The granular nature of the exine is very clear. The transparent trilete-like suture is due to the rupture of exine, ×88.

Photo 3. *Triletes* sp.—The papillæ in surface view can be clearly seen, at a few places they can be seen in optical section also, ×41.

Photo 4. *Triletes singraulensis* sp. nov.—Verrucose nature of exine is clearly seen, ×76.

Photo 5. *Triletes singraulensis* sp. nov.—Verrucose nature of exine even better than in Photo. 4, contact areas, and suture lines are also discernible, ×75.

PLATE IV

Photo 6. *Triletes singraulensis* sp. nov.—Another well preserved specimen, ×87.

Photo 7. *Triletes elongatus* sp. nov.—Dark specimen with folds, ornamentation not very clear, ×50.

Photo 8. *Triletes elongatus* sp. nov.—Both proximal and distal ornamentation seen, ×62.

Photo 9. *Triletes brasserti* Stach and Zerndt.—Specimen showing sinuous suture lines, ×77.

Photo 10. *Triletes brasserti* Stach and Zerndt.—An overmacerated specimen, which shows very clearly the sinuous nature of the suture lines, ×75.

Photo 11. *Triletes sp.*—A badly preserved specimen with folds, ×44.

Photo 12. *Triletes punctatus* sp. nov.—Specimen showing ornamentation and the neck with probably two carbonised (?) abortive spores, ×50.

PLATE V

Photo 13. An unknown form, probably a seed, ×35.

Photo 14. *Cystosporites indicus* sp. nov.—Seed megaspore, the membrane can be seen at a few places, ×256.

Photo 15. *Cystosporites indicus* sp. nov.—The outer membrane can be clearly seen at the proximal side, an abortive dark spore can also be seen, ×24.

Photo 16. Sporangium A.—The dark central area may represent a megaspore, ×50.

Photo 17. *Triletes papillarius* sp. nov.—Specimen showing the papillæ and the flat lobular area at the junction of the three suture lines, ×110.

STUDIES ON THE MORPHOLOGY AND ECOLOGY OF THREE SPECIES OF *DICHANTHIUM* WILLEMET.

By S. C. Pandeya

Botany Department, University of Saugar

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Introduction

The genus *Dichanthium* Willemet belongs to the tribe *Andropogoneæ* of sub-family *Panicoideæ*. It is characterised by (i) having different sexes in each pair of spikelets which also differ in shape and size; (ii) the awnless pedicelled spikelet is male or neutral; (iii) the sessile spikelets of lower and upper 1–3 pairs are male or neutral, and awnless; (iv) the lower glume of sessile spikelet is broad; (v) the spikelets are arranged in imbricate orde; and (vi) the racemes are digitate.

Haines (1924) has recorded 3 species of the genus, *viz.*, *D. annulatum* Stapf (Syn. *Andropogon annulatus* Forsk.), *D. caricosum* A. Camus (Syn. *Andropogon caricosus* L.), and *D. Clarkei* Haines (Syn. *Andropogon Clarkei* Hack.). The last named is an annual. Four other species besides the first 2 have been recorded from Bombay by Blatter and McCann (1935). These are *D. panchganiense* Blatter and McCann, *D. armatum* Blatter and McCann, *D. McCannii* Blatter and *D. serrafalcoides* Blatter and McCann.

Linnæus (as quoted by Haines, 1924) described *Andropogon caricosus* L. (*D. caricosum*) with solitary spike, and Willdenow has said 'leaves with sparse hairs and sheaths hirsute at base'.

Haines (1924) has further described a robust variety of *D. caricosum*, *i.e.*, var. *mollicomus* based on *Andropogon caricosum* L. var. *mollicomus* Hack. This variety is considered to be the same as *Dichanthium nodosum* Willemet by Fischer in Gamble's *Flora of the Presidency of Madras* (1934).

Collections of species of *Dichanthium* from Sagar were identified at the Forest Research Institute, Dehra Dun, as *D. annulatum* Stapf, *D. caricosum* A. Camus and *D. nodosum* Willemet. The description of Haines (1924) for *D. caricosum* A. Camus tallies with the stunted plants of the species in our region. The plants of this species have 1 or 2 spikes in over-grazed and dry areas. The species grows in robust form (upto 7–8 ft. high) in reserved grasslands, and in association with shrubs in gardens and cultivated fields where they get a regular supply of water all the year round. The other species, *i.e.*, *D. annulatum* Stapf seems to be much drought-resistant.

In view of certain variations observed in these species, it is not out of place to quote the following remark of Burns, Kulkarni and Godbole (1925):

"One fact we are convinced that both species, and especially *A. annulatum* are variable. It seems to us that throughout the whole science of taxonomy it is now time that the practice of naming varieties and species from casually collected specimen, dried and pressed, should be stopped, and that the only scientific method of pure culture should be substituted."

The present study includes the morphology and ecology of *Dichanthium annulatum* Stapf, and *Dichanthium caricosum* A. Camus. together with culture experiments with *D. caricosum* A. Camus, in light of the abovementioned observations.

Morphology

Dichanthium annulatum Stapf.

Roots: Extensive, spreading and going down upto 2 ft. Secondary roots are given off from the nodes of the branches trailing over the ground. *Stems*: Tufted, perennial, with rhizomiferous main stem. Branches arise from procumbent base or ascending from a geniculating base, 1–3 ft. high, occasionally rooting at the nodes. Nodes are purple and mostly bearded. Hairs loosely tufted, longer than the length of node. Internodes compressed, groved on the surface corresponding to the back of the sheaths and pale or purplish in colour. *Leaves*: Linear, narrow, with rounded base, acuminate, sparsely hairy, upper surface having tubercle-based hairs. Leaf-blade somewhat rigid. Leaf-sheath glabrous, sometimes with ciliate margins, shining green or purplish in colour. Ligule, short, membranous, truncate, 1·5 by 1·5 mm. (Fig. 1). *Spikes*: The spikes are sub-digitate, 1–15 in number, erect or slightly spreading, pale when young and purplish or brown when old. The spikes vary in length from 1 to 2 in., sometimes branching; the stalk of the racemes is long, smooth, slender, very shining and mostly pinkish in colour. Rachis of the racemes many jointed; joints of the rachis and pedicels 1·5 to 3 mm. The peduncle of the spikes is 3 to 5 mm. long, thin, slender, shining, pinkish in colour, with a swollen base. Base, groved, glabrous or with a ring of hairs (*see* Fig. 7). *Spikelets*: Spikelets are in pairs of one sessile and one pedicelled, sub-imbricating on the rachis. Both spikelets are nearly equal in length.

Sessile spikelets: With a thick callus shortly bearded, hermaphrodite, 3–4 mm. long, ovate-oblong, compressed, dorsally awned. Awns absent in the basal and terminal few homogeneous spikelets. Lower glume is papyraceous, 3-4 mm. long, narrow lanceolate, obtuse or hardly truncate, 5–10 keeled, margins infolded. Marginal keel spinulous ciliate. The rest with spreading hairs. Hairs near the margins of the upper portion of the glume are as long as the glume, and have large orange-shaped bases; tubercles yellow in colour. The back of the glume is very shortly and scantily villous. The margins narrowly clasp the upper glume. Upper glume is hyaline, lanceolate, 3–4 mm. long, 3 keeled, depressed at the middle keel. The glume has acute apex, entire margins and is glabrous. Glume iii is hyaline, nerveless, very much shorter than the upper glume.

FIG. 1. *Dichanthium annulatum* Stapf—1. A portion of raceme. Observe the loose imbricate fittings of spikelets on spike. 2. A pair of spikelet. *a*, sessile, awned; *b*, Pedicellete. 3. Lower glume of sessile spikelet. 4. A cross-section of the lower glume of sessile spikelet showing the infolds of margins and position of nerves. 5. Upper glume, 3 nerved, hyaline. 6. Pedicelled spikelet. A—Lower glume; B—Upper glume. 7. Ligule of leaf. 8. Tubercular-base of the hair of glumes.

The awn emerges with a hyaline base from below the dorsal side of the ovary, 2–2·5 cm. long, column scabrid. Ovary glabrous; caryopsis obovate, flat dorsally. Pedicelled spikelets are male and awnless. The pedicel is equal to or slightly longer than half the length of the sessile spikelet. Lower glume is obovate with a mucronate base, margins infolded, with long tubercle based hairs throughout, more along the margins. Upper glume is generally small, 3-nerved, margins ciliate. Glume iii—is stout, and hyaline. Stamens are 3 with purple-dotted green anthers.

Dichanthium caricosum A. Camus

Roots: as in *D. annulatum* Stapf. *Stems*: are erect or ascending from a creeping base, rooting at the nodes. Culms 20 to 80 cm.

Stem upto 1·5 metres tall, when erect in association with shrubs. Nodes villous or mostly glabrous. Hairs, half the length of the node closely tufted. (The villous nodes were mostly found in plants from grazed grasslands.) Stem pale to greenish-purplish. *Leaves*: Leaf-blade rigid, narrowly linear, 15–50 cm. long by 2·5–7 mm. broad, glabrous, margins scaberulous, median nerved and white above. Base with a few small hairs. Leaf-sheath glabrous, margins mostly smooth. Ligule membranous, 0·35 by 1·5 mm., slightly truncate apex (Fig. 2).

FIG. 2. *Dichanthium caricosum* A. Camus.—1. Portion of raceme. Mark the close imbricate fittings of spikelets. 2. A pair of spikelets. *a*, Sessile; *b*, Pedicillate. 3. Lower glume of sessile spikelet. 4. Cross-section of sessile spikelet showing the margins. 5. Upper glume of sessile spikelet. Similar is the upper glume of pedicelled spikelet. 6. Pedicelled spikelet-lower glume. 7. Ovary (*O*) and stigma (*S*), bifid-feathery. 8. Anther-lobes spotted. 9. Ligule of the leaf. 10. Inverted cup-shaped base of the hairs of glumes.

Spikes: 1 to few (upto 5 were recorded) variable in length from 3·75–8·75 cm. Racemes pale to greenish pink in colour. Swollen base of the rhachis, the peduncle and the internodes between the joints of successive spikes clothed with fine silky hairs (*see* Fig. 8). *Sessile spikelets*: closely imbricate; hermaphrodite. Lower and upper few

spikelets male or neutral and awnless. Spikelets dorsally compressed. Callous rounded and glabrous. Lower glume obovate or obovate-oblong, 3–5 mm. by 1·5–3 mm., apex 3-toothed. Keels 10–13, not reaching the apex. Glume pink to crimson in colour near the tip. Margins inflexed. Back hairy; hairs very small and woolly, with inverted cup-shaped base. Below the middle the glume is sparsely hairy. Upper glume—thin papyraceous, ovate or obovate being clasped by the margins of the lower glume. Keels—3, margins sparsely ciliate. Glume iii—hyaline, small, nerveless and shining. Scaberulous awn 2–2·5 cm. long. *Pedicelled spikelet*: male or neutral. Pedicels much shorter than half the length of sessile spikelet. Lower glume 10–15 nerved, margins scabrid; obovoid or oblong. Hairs small, on the upper side of the glume, margins broadly infolded. Upper glume, membranous, about equal to the first glume; nerves—3, margins ciliate and infolded. Glume iii—small, hyaline, nerveless, linear, small, apex narrowed and deeply bifid. There are 3 stamens as in the former species.

Blatter and McCann (1935) have distinguished *D. caricosum* A. Camus and *D. annulatum* Stapf, on the basis of 4 characters, *viz.*, (1) Habit, (2) Nodal hairs on stem, (3) Colour of inflorescence, and (4) Hairs on inflorescence. In addition to these the 2 species can be distinguished in the field by the following characters arranged in sequence of prominence.

TABLE I

Distinguishing Characters in the Morphology of Dichanthium annulatum Stapf and Dichanthium caricosum *A. Camus*

No.	*D. annulatum* Stapf	*D. caricosum* A. Camus
1	Joints and nodes of the peduncle glabrous or sparsely hairy.	Peduncle including its nodes finely white-woolly, always.
2	Spikelets arranged in sub-imbricate (loose) order.	Spikelets closely imbricated.
3	Spikes 1 to 15 in number, pinkish or dark-red in colour.	Spikes 1 to 5 in number, pale or olive green to greenish-pink.
4	Long (longer than the total length of the lower glume) yellow tubercular based hairs on the lower glumes of both the spikelets. The hairs are generally present on the upper half of the glume.	Hairs short and tufted-silky. Somewhat uniformly studded throughout the upper surfaces of the lower glumes of both the spikelets.
5	Pedicels of the ped. spikelets equal or slightly longer than half the length of sessile spikelets.	Pedicels of the pedicelled spikelets much smaller in length than half the length of the sessile spikelets.
6	Nodes always villous with long hairs.	Nodes mostly glabrous; young branches generally with villous nodes.
7	Ligule 1·5 by 1·5 mm. with truncate apex.	Ligule 0·35 by 1·5 mm. with slightly truncate apex.

VARIABILITIES OF *D. caricosum* A. Camus

In Table II are given the descriptions as given in different floras for *D. caricosum* A. Camus.; var. *mollicomus* Hack.; and *D. nodosum* Willem. From the descriptions, it is clear that the species is much variable with regard to shape and size. It is also seen from the table that *D. caricosum* var. *mollicomus* Hack. is identical with *D. nodosum* Willem.

TABLE II

Author's name	*D. caricosum* A. Camus (Syn. *A. caricosus* L.)	*D. caricosum* var.– *mollicomus* Hack.	*D. nodosum* Willem.
Haines (1924) p. 1039	*Stem:* 1–2 ft. *Leaves:* 2–5″ (5–12·5 cm.) by 0·1–0·15″ (3–5 cm.)– ("sometimes larger outside our area"). *Spikes:* 1–4. Sessile spikelets-callous glabrous. Gl. i: 0·14–0·15″ (4–5 mm.) denticulate at tip. Tip 2 toothed. 5–7 nerved between 2 keels. Gl. ii : 3 keeled. Joints and pedicels 0·04–0·05″ (1–2 mm.) villous one side. Pedicelled spikelet : 0·15″ (5 mm.) Gl. i : 11 nerved, laxly hairy. Gl. ii—margins inflexed.	This appears to be more distinct. A specimen collected from Bilaspur is a very robust plant with 3–4 broad spikes, upto 3″ (8 cm.) long and 0·15″ (4–5 mm) wide. Very hairy peduncles and toothed bidentate winged broad glume-i. The nodes are pubescent.	
Hooker (1897) Vol. vii, p. 196	*Stem*: 1–2 ft. *Leaves:* 6–8 by 0·1–0·25″ (15–20 cm. by 3–8 mm.) Spikes : ⅛–¼″ (4–10 mm.). Joints and pedicels ⅓ of the spikelets. Sessile spikelets : 5–7 nerved, Gl. ii : 3 keeled. Pedicelled spikelets smaller than the sessile one. A very variable grass.	*Stem:* pubescent below the spikes. Gl. i–3 toothed, hairy all over.	Synonymous to var. *mollicomus*, also syn. *Dichanthium nodosum* Ustri, Annals XVIII (1796), Syn., *Andropogon mollicomus* Kunth Revis.
Bor (1941) p. 118	*Culms:* 30–60 mm. *Leaves:* 15–20 cm. by 2·5–5 mm. Inflorescence: solitary or subdigitate 2–4 nate, 2·5–10 cm. long. Joints and pedicels 1·3–1·6 mm. Sessile spikelets: 4–5 mm. long. Gl. i : ciliate. Gl. ii : longer than the sessile spikelets.	not mentioned	

D. caricosum A. Camus seems to be less drought-resistant. It shows stunted growth on sandy soil of poor moisture content. In summers, in overgrazed grasslands also, it shows stunted growth having as few as one spike per peduncle. In culture with favourable moisture supply the depauperate forms collected from these regions, grow into

normal plants. Conversely the seeds of the robust variety can be grown into stunted plants on poor dry soils.

In view of the abovementioned observations the following study was made:

Ten localities were chosen on the basis of soil moisture content for a study of the species. The data obtained were: height of the culms standing erect from the prostrate base; average number of spike per raceme; average number of spikelets per spike; length and breadth of lower glume of sessile spikelets and colour of the spike. The observations have been correlated with the usual factors of soil-water and biotic operations. The results are given in Table III.

TABLE III

Morphological Characters of the Plants of D. caricosum *A. Camus from Different Localities*

Date: March 1952

	Locality	Soil-water in % of dry wt.	Aver. height of plants	Aver. No. of spikes per raceme	Aver. No. of spikelets per spike	Length of Gl. i. of sessile spkt. in mm.	Breadth of Gl. i. of sessile spkt. in mm.	Colour of spikes	Remarks
1	Along water drains supplying water to crop fields in University gardens and farm.	27·42	52 cm.	2 3 4 2 3	34 46 46 32 38	3·5 4 4 3·7 3·7	1·7 1·8 1·8 1·8 1·8	Greenish brown	No grazing
2	Crop fields, University gardens and farm.	9·64	75	2 3 3 2 4	32 40 30 34 40	3·7 3·9 3·6 3·6 3·8	1·8 1·8 1·7 1·7 1·8	Purplish green	No grazing
3	Crop fields, Makronia village.	8·30	75	4 3 2 1 2	64 48 36 28 32	4·2 4·0 3·8 3·7 3·7	2·0 2·0 1·8 1·7 1·7	Purplish green	Very mild grazing
4	University Botanical Gardens.	8·05	75	3 3 3 4 4	36 36 44 44 40	3·7 3·7 3·9 4·0 3·8	1·7 1·7 1·9 1·9 1·8	Purplish green	No grazing and no cutting
5	Lime-rich soil on open slope.	2·55	20	1 2 2 1 1	18 20 22 18 18	3·4 3·4 3·4 3·5 3·4	1·6 1·6 1·6 1·7 1·7	Purple	Severe grazing

TABLE III—(*Contd.*)

	Locality	Soil-water in % of dry wt.	Aver. height of plants	Aver. No. of spikes per raceme	Aver. No. of spikelets per spike	Length of Gl. i. of sessile spkt. in mm.	Breadth of Gl. i. of sessile spkt. in mm.	Colour of spikes	Remarks
6	Enclosure area in University Botanical Gardens.	11·83	105	4 4 3 3 4	48 50 54 48 48	4·0 4·0 4·2 4·0 3·9	1·8 1·8 2 1·8 1·8	Greenish brown	No grazing and no cutting
7	Along high hedges in the University Botanical Gardens.	10·23	2 metres	4 4 3 3 3	60 60 54 54 52	4·2 4·2 4 4 4	2·0 2·0 1·9 2·0 2·0	Greenish brown	No grazing and no cutting
8	University grounds (open-plateau)	3·79	24	1 2 1 1 1	30 36 44 34 28	3·5 3·7 3·7 3·7 3·5	1·7 1·8 1·8 1·8 1·7	Purple	Severe grazing
9	Plateau of Gambheria village.	5·66	32	2 2 2 2 2	36 36 38 32 36	3·7 3·7 3·7 3·5 3·7	1·8 1·8 1·8 1·7 1·8	Greenish purple	Severe grazing
10	University grounds—open slopes.	6·45	32	4 1 2 3 2	42 36 38 40 38	3·8 3·7 3·7 3·8 3·7	1·8 1·7 1·8 1·8 1·8	Greenish purple	Occasional grazing

Correlation of plant growth with the habitat factors is always a difficult study, as there is never a single factor working exclusively. A number of environmental factors usually work at a time of which some may be more dominating. However, in the present case we may put that primarily the growth of this species depends upon a good supply of available water and also upon less of biotic disturbance.

Effects of grazing and drought upon the plant can be observed from Table III and Fig. 3, as follows:—

Morphological features: Reduced size of erect stem ; reduction in the number of spikes per raceme; reduction in the number of spikelets per spike; and reduction in the length and breadth of lower glume of spikelets.

Physiological: Development of red pigments, and initiation of early flowering.

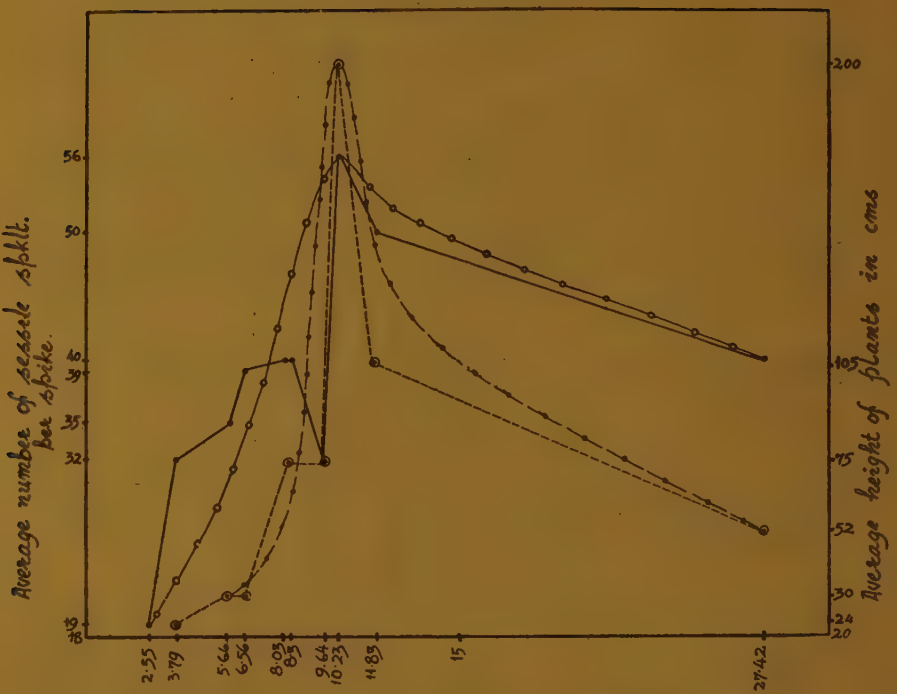

FIG. 3. Soil-water in % of dry wt. of soil from different habitats as given in Table III.

Apart from the abovementioned characteristics the following points are worth noting:—

(i) Comparing the readings from the localities 1 and 2 (*cf.* Table III) it seems that a further increase in the percentage of available water in the soils brings an overall dwarfening of the plants.

(ii) Again, from the readings for the localities 6 and 7 of Table III, it is seen that the plants attain a height of even 2 meters. Probably in this case the overgrowing hedges provide support to the weak and thin stem growing under shade.

CULTURAL EXPERIMENTS

Cultural experiments were undertaken, in the month of March, 1951, in order to confirm the variabilities of *D. caricosum* A. Camus. Plants with stunted growth having little foliage and mostly with one spiked racemes were brought from grazed areas. A few plants were also transplanted from a patch having heavy interspecific competition. These plants were put in plots of sandy loam under fence in the Botanical Gardens 8 inches apart from each other. The plots were watered on alternate days, and no fertiliser or manure was supplied. The following readings were taken after 1 year, in the month of February, 1952.

TABLE IV

(1) *Characters of Original* D. caricosum *A. Camus Plants Before the Transplantation*

Locality	Condition of growth	Height of plants in cm.	Length of internodes in cm.	No. of Racemes	Aver. No. of spikes per raceme	Length of spikes in cm.	No. of sessile spkts.	Length ot Gl. i of sessile spkt. in mm.	Breadth of Gl. i of sessile spkt. in mm.	Aver. length of leaf in cm.
1 Crop fields University grounds	Under heavy interspecific competition	80	15·8	21	1	4·1	26	3·7	1·6	11·5
2 Botanical Gardens	Occasional cutting	35	10·5	8	2	6·4	34	3·8	1·8	17·5
3 Open lime rich slope	Under severe grazing	15	4·6	1	1	3·1	18	3·4	1·6	5·4
4 University plateau	Under severe grazing	20	4·4	2	1	3·8	26	3·7	1·7	6·5
5 do	do	15	4·0	2	1	3·6	22	3·5	1·7	6·3

(2) *Measurements for an average plant after one year of Controlled Growth*

Date: February, 1952

Culture plant. No cutting, no grazing and no manuring. Watered on alternate days	95	11·5	16	3	7·6	56	4·0	1·8	19·0

A polygraph (Fig. 4) has been drawn to designate the growth of *D. caricosum* A. Camus as found in localities 1, 3 and 4 (of Table IV) before the culture experiments and the resultant growth after 1 year of controlled development.

It is seen that diagrams 'HLSGH' and 'hlsgh' are much similar in shape.

It is found that the lengths of the leaf and the spike are correlated in growth as shown in Fig. 5. The data so plotted are taken from Table IV (for points 'a' and 'b'). Points 'c' have been put for the spike-leaf relation of a number of robust plants, as found in nature. The variations are, therefore, continuous and belong to a uniform population of the species.

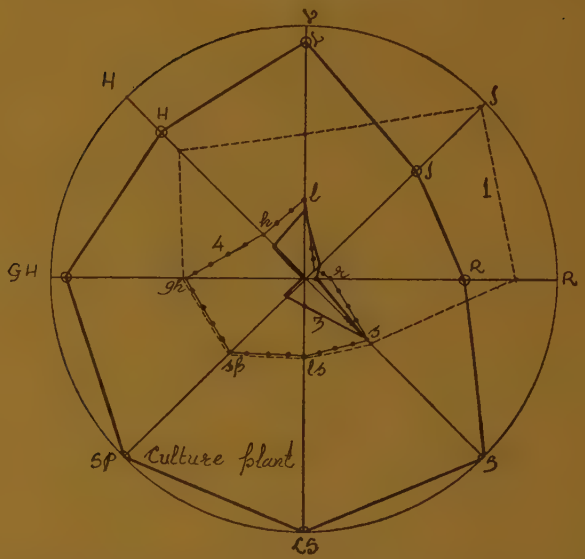

FIG. 4. Polygraph for the size and shape of the plants from localities 1, 3 and 4 (*cf.* Table IV) before the culture experiment and of a plant after one year of culture experiment of *Dichanthium caricosum* A. Camus (*H*, Height of plants; *L*, Average length of leaf; *I*, Length of internode; *R*, Number of racemes; *S*, Average number of spikes per raceme; *LS*, Length of spikes; *SP*, Number of sessile spikelets; *GH*, Length of glume I of sessile spikelet; and *GB*, Breadth of Glume II of sessile spikelet).

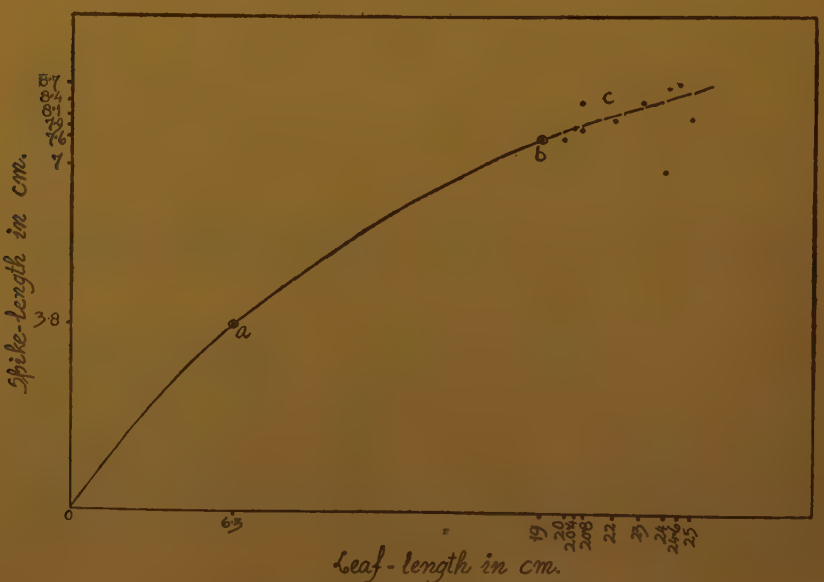

FIG. 5. Leaf-spike relation of *D. caricosum* A. Camus.

Distribution

D. caricosum A. Camus and *D. annulatum* Stapf are fairly well distributed in India. According to Hooker (1897) *D. caricosum* A. Camus is distributed on plains and low hills of India from Scind to Burma, and the Andaman Islands (not in N.W. India) and southwards to Ceylon. The species is further distributed in Mauritius and China. In Bihar and Orissa, Haines (1924) reports its frequent occurrence in a number of places. Its presence is reported on the Banks of Brahmaputra and in Lakhimpur in Assam by Bor (1936). Bor (1941) in 'U.P. grasses' shows its distribution in South Kheri Bundelkhand and elsewhere in the plains. In South-India, Achariyar and Mudaliyar (1921) write that it is less common than *D. annulatum* Stapf. They report that it grows upto 4–5 ft. in black cotton soil in Bellary District. Describing the grasslands of Gujerat, Deccan, Southern India and Bombay, Burns, Kulkarni and Godbole (1925) have described both the species of *Dichanthium* to be amongst few more important grasses.

The following map showing the distribution of both the species of *Dichanthium* is based upon records available in literature (Fig. 6).

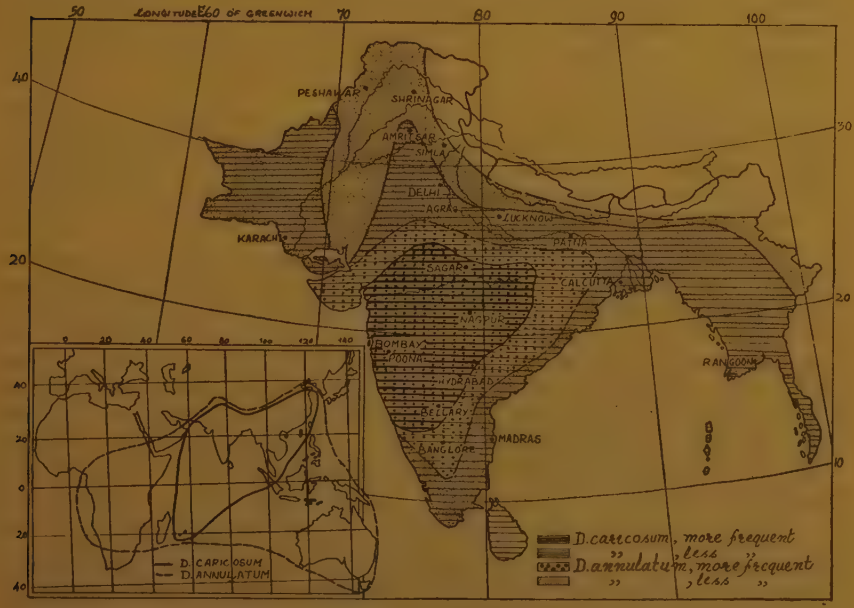

Fig. 6. Distribution of *D. caricosum* and *D. annulatum* in India, Burma, Pakistan and elsewhere.

D. annulatum Stapf is distributed throughout the hills and plains of India, from Kashmir westward to Bengal and southward (not in Ceylon). Hooker (1897) further describes its distribution in Trop. Africa, China, Australia and Pacific. Bor (1941) has shown its occurrence

in almost all the districts of U.P. and Assam. The author has noted its presence on the 'Jakku' peaks in Simla (about 8,000 ft. above sea level), although the grass was in much stunted growth.

Ecology

1. *Duration.*—Both *D. annulatum* Stapf and *D. caricosum* A. Camus are perennial. The species in open grasslands* pass over the hot dry season as dormant stumps. There is always present a cushion of old leaves at the base. The perennating organ in the 2 species is stolon (underground rhizome); this is more conspicuous in case of *D. annulatum* Stapf.

Unlike *D. caricosum* A. Camus, *D. annulatum* Stapf never dries completely and one can see a few green leaves present in hot dry season.

Seeds start germinating, in nature, after a few showers in June, and by the end of July the culms attain a height of 1 ft. or so. During the first year of emergence of plants from the seeds, there is not much of vegetative growth. The racemes, too, are fewer in number. Stolon buds of the first year spread out with more vigour next year. More shoots are thus added. The stump or tuft gradually develops and acquires a 'basket-form' in both the species. As has been earlier observed *D. caricosum* A. Camus, in protected places grows much like a twiner (upto 6 to 7 ft.) in association with other shrubs.

2. *Phenology.*—In Sagar, *D. annulatum* Stapf starts flowering from November or late October and may continue so upto March or April. However, excepting the rainy season it is not infrequent to find a few plants in flowers all the year round. *D. caricosum* A. Camus flowers from end of September and lasts till March.

3. *Fruiting.*—The caryopsis of *D. caricosum*, liberated together with all the glumes, is shed singly from the spikes. The dispersal starts from the apex downward. Whereas the fruits of *D. annulatum* Stapf liberated similarly, are shed in twisted lumps of 2 to 6 seeds. The assemblage of the seeds seems to have been brought about with the help of the twisted awns and the long hairs of the glumes. In case of *D. caricosum* A. Cumus the awns are mostly shed before the fruits are mature for dispersal, and hence they do not form any lump. Whether this phenomenon is advantageous for seed dispersal cannot be said at present.

Seeing the mode of dispersal *D. annulatum* Stapf should have a patchy growth of plants in the subsequent year wheras *D. caricosum* A. Camus plants should grow uniformly distributed. However, the absence of a patchy growth of plants of *D. annulatum* Stapf cannot be accounted at present.

D. annulatum Stapf and *D. caricosum* A. Camus grow abundantly in Sagar (M.P.) on 'premature to mature soil' (Pandeya, 1952) consisting of sandy-loam with light to moderate admixture of coarse lime

* Unfenced, open to grazing.

of intertrappean origin. The soil is rich in mineral elements like iron, aluminium, calcium, magnesium, etc. Much iron, however, seems injurious to the species, since they do not grow on leached soils. Although both species seem to be calcicolous yet *D. annulatum* Stapf is probably more tolerant to lime. This species seems also to withstand waterlogging of 'not long duration'. Achariyar and Madaliyar (1921) write that the two grasses like sheltered places; and *D. caricosum* A. Camus grows in places with sufficient moisture in soil. Bor (1941) observes for *D. caricosum* A. Camus that 'it favours rather dry and sandy habitats,' and puts *D. annulatum* Stapf amongst the grasses growing in 'moderately moist places'. He further puts *D. annulatum* Stapf amongst the grasses 'most frequently found in grazing grounds'. These grasses 'maintain themselves because of their perennial and prostrate habit whereby the stem is pegged down to the soil by rootlets from the nodes'.

The presence of *D. annulatum* Stapf in Simla near Viceregal Lodge and Jakku Hills upto 8,000 ft. above sea level may show its tolerance to altitude and extreme conditions of temperature.

The usefulness of *D. annulatum* Stapf as a species for erosion control is being studied and will be discussed in another paper.

Summary

The paper deals with morphology, physiology and ecology of two species of the genus *Dichanthium* Willemet, *viz.*, *D. annulatum* Stapf and *D. caricosum* A. Camus.

Both are excellent fodder grasses.

The two species are much similar in appearance. Distinctive characters differentiating the two species are given in a tabular form in the text.

Both the species are much variable with regard to shape and size of branches, leaf, spike, etc., in response to environment. *D. annulatum* Stapf seems to be more drought resistant and grows in a great variety of habitats. *D. annulatum* Stapf stands cutting well but overgrazing seems harmful to it. *D. caricosum* A. Camus is probably more sensitive to water and grows in stunted condition with overall reduction in the size of branches, leaf and spike in places with less soil-water.

On the basis of variability, morphology, culture experiments and analylical data it is observed that *D. nodosum* Willem. (Syn. *D. caricosum*-var. *mollicomus* Hack.) is an ecological form of *D. caricosum* A. Camus.

It has been shown that the same plant of *D. caricosum* A. Camus growing in sandy and less watered places with one spike per raceme if given favourable water-supply may grow into a form resembling var. *mollicomus* Hack.

Acknowledgements

I am greatly indebted to Dr. R. Misra, Head of the Department of Botany, for the kind guidance, valuable suggestions, and advice throughout the course of study. My thanks are also due to Mr. H. R. Bhargava for valuable criticism from time to time.

Literature Cited

Achariyar, K. R. and Mudaliar, C. T. 1921. A Hand-Book of South Indian Grasses. Madras Government Press.

Blatter, E. and McCann, C. 1935. The Bombay Grasses. Imp. Counc. Agri. Res. Scientific Monograph No. 5. Delhi.

Bor, N. L. 1936. Flora of Assam. Vol. 5. Gramineæ. Government of Assam.

———. 1941. Common Grasses of United Provinces. Indian Forest Rec. (New Ser.) Botany. 2: No. 1.

Burns, W. *et al.* 1916. Bull. Dept. Agri. Bombay. No. 78.

———, Kulkarni, L. B. and Godbole, S. R. 1928. A study on Some Indian Grasses and Grasslands. Mem. Dept. Agri. Ind. Bot. Ser. 14: 1, 57.

Fischer, C. E. C. 1934. (Gamble, J. S.'s) The Flora of the Presidency of Madras.

Haines, H. H. 1924. The Botany of Bihar and Orissa. Adlard & Sons and New Man, London.

Hooker, J. D. 1897. Flora of British India. Vol. 7. Reeve & Co. Ashford Kent.

Pandeya, S. C. 1952. Succession in Grasslands of Saugar, Madhya Pradesh. The Saugar University Journal. 1: 111–29 (1951–52).

1038-58 Printed at The Bangalore Press, Bangalore City, by C. Vasudeva Rao, Superintendent and Published by Dr. T. S. Sadasivan Business Manager, The Indian Botanical Society University Botany Laboratory Triplicane Madras.

FIG. 7. Raceme of *Dichanthium annulatum* Stapf. having 4 spikes. Note the long, smooth, slender stalk of the raceme. Peduncles of the spikes are glabrous. Base of the peduncle is groved, and with a ring of hairs.

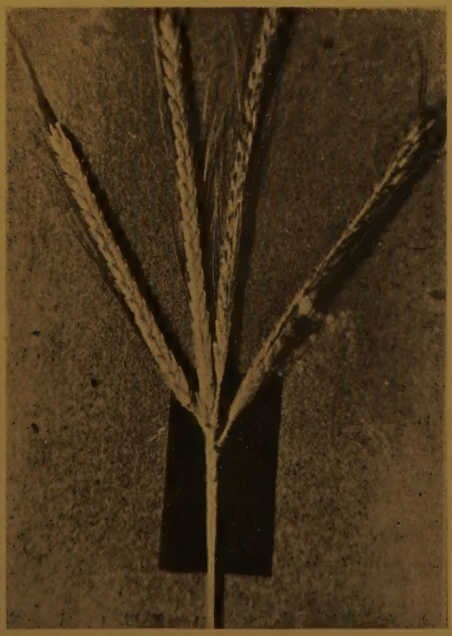

FIG. 8. Raceme of *Dichanthium caricosum* A. Camus having 4 spikes. Note the broad glumes closely fitted. Swollen base of the rachis, the peduncle and the internodes between the joints of successive spikes are clothed with silky hairs (Having the black background).